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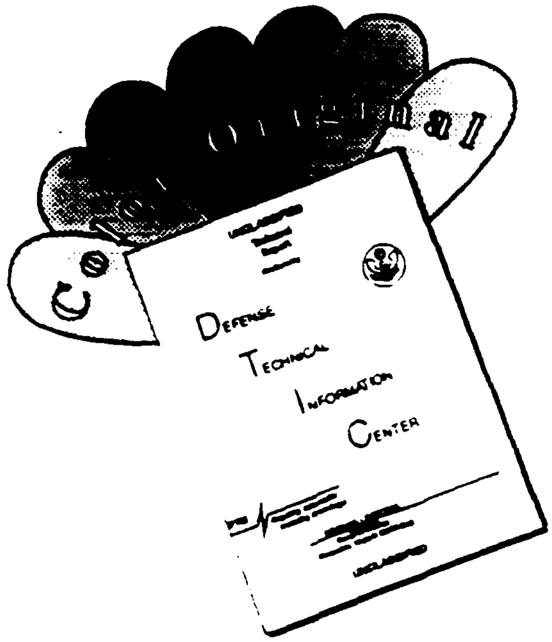

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SARGENT BEACH, TEXAS: A STUDY OF LOGISTICAL CONSTRUCTABILITY ISSUES ON A LARGE PROJECT

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Date Submitted: November 15, 1993

ABSTRACT

SARGENT BEACH, TEXAS: A STUDY OF LOGISTICAL CONSTRUCTABILITY ISSUES ON A LARGE PROJECT

by

JOHN ELLIOTT WOOD, B.S.

SUPERVISING PROFESSOR: G. EDWARD GIBSON, JR.

This thesis presents an analysis of the logistical constructability issues identified for the Sargent Beach, Texas, Shoreline Protection Project. The U.S. Army Corps of Engineers, Galveston District recognized the advantages of employing constructability concepts and agreed to establish a relationship with the Construction Industry Institute (CII) in order to achieve a constructability study on this project. By incorporating construction knowledge and experience early in the planning and design phase, the District felt that it could significantly enhance overall project success. Constructability concepts have been shown to decrease project duration, maximize construction efficiency, and optimize overall cost. This thesis was developed in conjunction with the CII study and concentrates on the logistical aspects of the project to include, construction materials, transportation and handling, and work site operations. In addition, a research methodology is outlined to assist future, similar studies in the area of logistical constructability issues. Conclusions and recommendations are presented based on the results of the analysis.

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1. INTRODUCTION

1.1. Purpose

In mid-September 1992, Mr. Carl Betterton, Chief, Engineering Division, U.S. Army Engineer District Galveston, contacted MG (Ret.) Charles I. McGinnis, Associate Director, Construction Industry Institute (CII), to explore the possibility of working together on a constructability study. After considering both the nature of the Sargent Beach Project with its peculiar requirements, and the fundamentals of constructability developed through the CII research program, it was agreed to establish a relationship directly between the Galveston District and CII.

This thesis was developed in conjunction with the CII study and its purpose is to concentrate on the logistical constructability aspects pertaining to the project, to include, construction materials, transportation and handling, and work site operations. An analysis of the data will identify logistical issues that can be improved through optimum use of construction knowledge and experience. In addition, this thesis will also attempt to outline a research methodology that can serve as a guideline for future studies in the area of logistical constructability.

1.2. Scope

Although data collected during this study may assist in future research, the scope is intended to focus only on the logistical issues pertaining to the Sargent Beach Project. The constructability analysis reported herein will be limited to review of the project following the general trace and using the basic design provided by the Corps.

The study scope envisions design review of: armor stone, sheet piling, and other materials to enhance productivity; a review of possible equipment types or the alternative use of innovative equipment to improve productivity; and an analysis of possible task sequencing to assure feasibility and to suggest methods improvements for cost control. Alternative methods have been considered, and potential problems associated with given construction tasks have been discussed and preferred options identified. Quality control issues have been identified and logistical support issues left to contractor judgment have been explored.

1.3. Thesis Organization

The purpose for conducting the CII Constructability Study is given in Chapter 2 along with an explanation of the contributing site conditions and a brief description of the selected plan and project status. The research methodology that the constructability team followed is outlined in detail in Chapter 3. The presentation and analysis of the research data are addressed in Chapters 4 (Materials), 5 (Transportation and Handling), and 6 (Work Site Operations). The conclusions and recommendations resulting from the research are provided in Chapter 7. Finally, Chapter 8 provides a research methodology outline to assist future studies in the logistical constructability arena.

2. PROJECT BACKGROUND

2.1. Brief History

The Gulf Intracoastal Waterway (GIWW) is a critical link in the inland waterway navigation system of the United States. Within Texas, the GIWW extends 423 miles along the entire Gulf of Mexico shoreline from the Sabine River to Brownsville, Texas. The existing configuration of the GIWW was completed in 1949 to its present dimensions of 12 feet (ft.) deep and 125-foot bottom width. As a link between Texas ports and those of the entire Gulf coast and the interior of the Nation, the GIWW offers an important commercial trade artery that supports a significant sector of the United States' economy. Waterborne Commerce data for calendar year 1988 show that over 16 million tons of commerce moved on the GIWW past the Sargent Beach, Texas, area (DA 1992).

2.2. Project Location

Sargent Beach, Texas, is located in Matagorda County between East Matagorda Bay and Cedar Lakes, about 170 miles north of Corpus Christi and 20 miles southwest of Freeport. The Sargent Beach study area, shown in Figure 1, encompasses that section of the GIWW between channel miles 411 and 421.5 measured from Harvey Locks, Louisiana. The GIWW in the study area generally parallels the Gulf of Mexico shoreline for about seven miles and is separated from the Gulf by a barrier island (Sargent Beach), varying in width from 650 to 900 feet, with the exception of one area which is less than 300 feet in width.

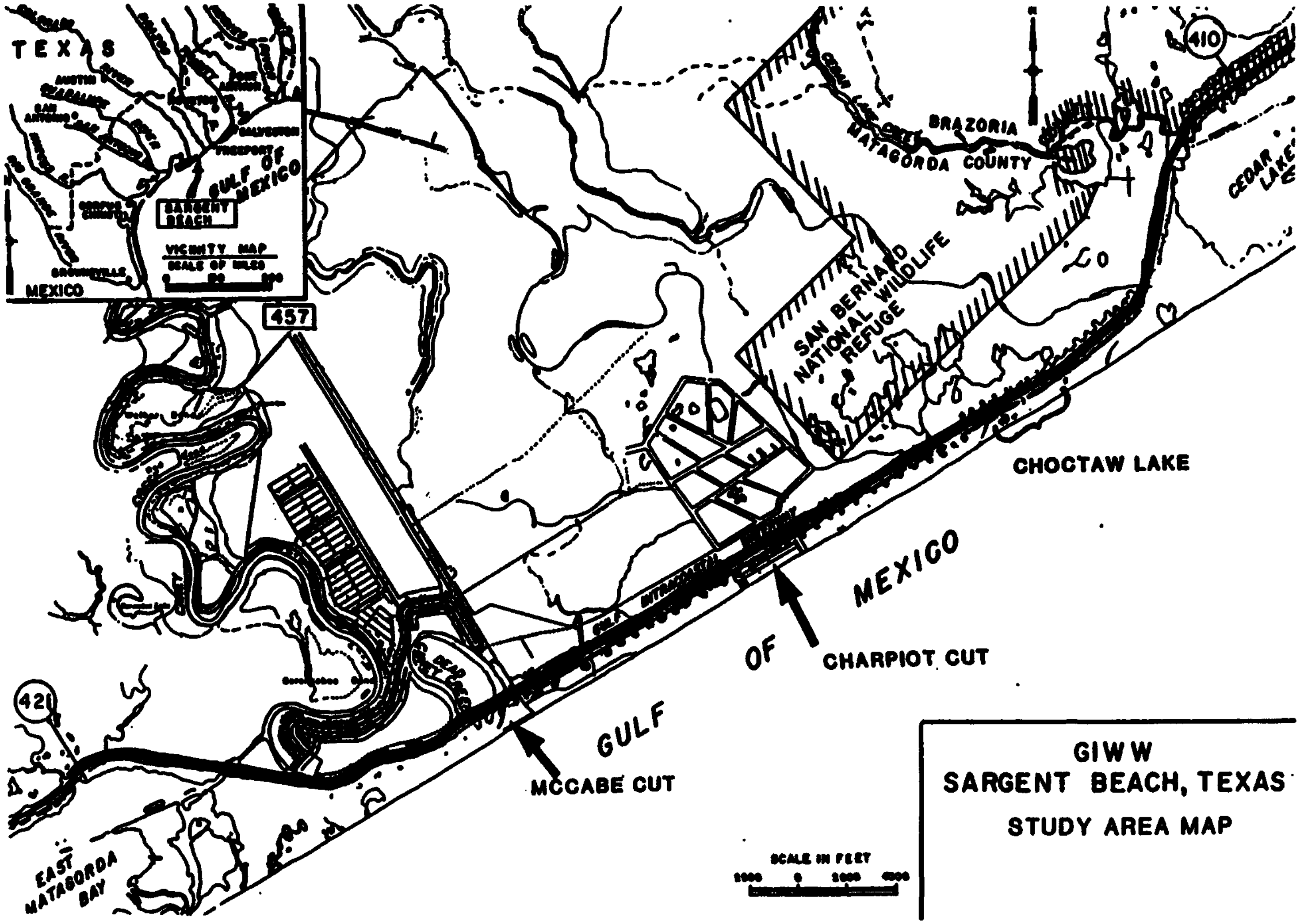


Figure 1. Sargent Beach Study Area

2.3. Problem Description

This barrier island, and numerous others along the Texas coast, provide protection to waterborne traffic from the incessant wave attack of the Gulf of Mexico. However, in the Sargent Beach area, the thin strand of land between the Gulf shore and the GIWW is eroding at an average rate of between 25 and 35 ft. per year. It is estimated that serious maintenance problems will develop in this area by the turn of the century, and within 10 to 15 years thereafter, the GIWW could be closed for extended periods of time following major storms. Severing the GIWW at Sargent would isolate about 250 miles of the GIWW southwest of Sargent Beach from the rest of the inland waterway system, resulting in major economic repercussions from shipping delays, shifts to alternative modes of transportation, or high costs for channel maintenance of the waterway. Fortunately, the Sargent Beach area is the only segment of the GIWW in Texas that is threatened or will be threatened in the foreseeable future by erosion from the Gulf of Mexico.

The photographs shown in Figures 2.a. and 2.b. provide an excellent overview of the current situation on Sargent Beach as of November 1991. Figure 2.c., taken in March 1988, and Figure 2.d., taken in July 1971, provide a good representation of how the erosion problem has destroyed numerous dwellings and is well on its way to breaching the entire island. The vacation home in Figure 2.d. (noted by the arrow) is the same house as the one that appears in the foreground in Figure 2.c. In Figure 2.d., the house noted by the arrow is a safe five to six housing rows back from the tidal action. Unfortunately, Figure 2.c., shows this situation has changed significantly, as the wave action from the Gulf has started to deteriorate the houses foundation.

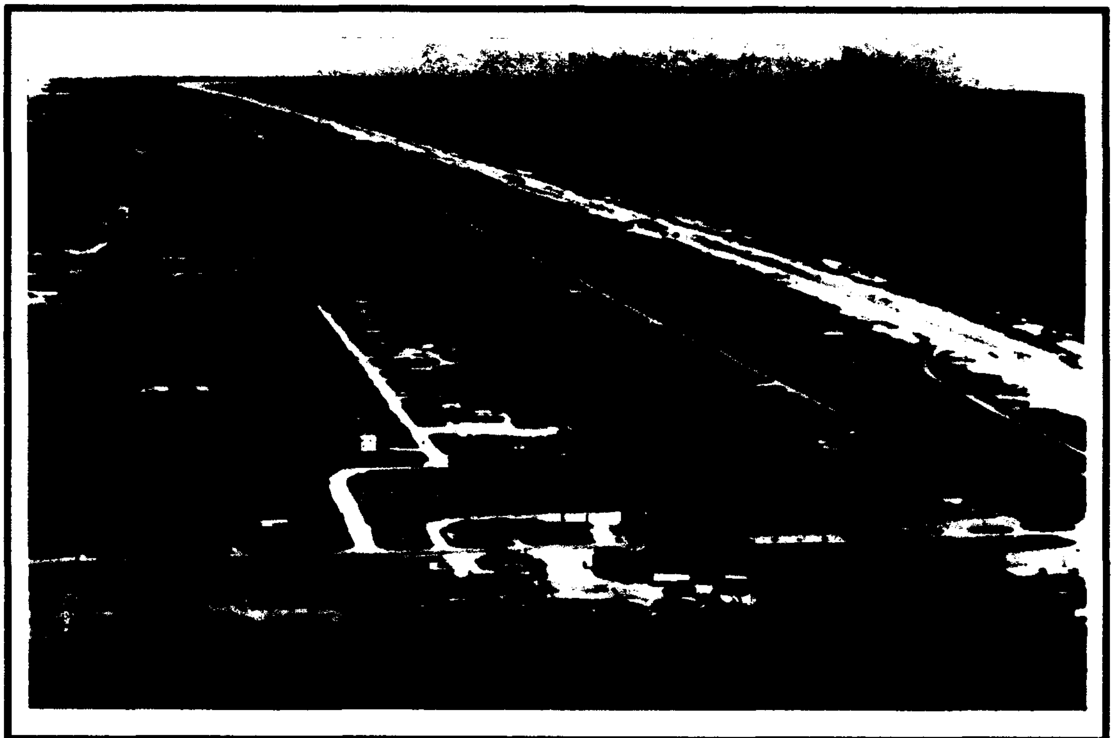


Figure 2.a. Sargent Beach, Texas - November 1991 (Vicinity FM 457 Swing Bridge)

Figure 2.b. Sargent Beach, Texas - November 1991 (Vicinity McCabe Cut)

Figure 2.c. Sargent Beach - March 1988 (Note: Wave Action Deteriorating Foundation of House in Foreground)

Figure 2.d. Sargent Beach - July 1971 (House Noted by Arrow is the Same House in Foreground of Figure 2.c.)

2.4. Project Alternatives

To prevent the interruption of GIWW traffic, Congress directed the Corps to conduct a study of remedial action. A wide range of alternative plans were evaluated which were formulated to protect the integrity of the GIWW. The alternatives evaluated included barrier-type plans such as sheet-pile walls and revetments, coastal-type plans such as offshore breakwaters and beach renourishment, and channel realignment plans. All of the plans evaluated were found to be economically feasible. However, all of the channel realignment plans would adversely impact large acreages of wetlands and would entail high mitigation costs.

After careful consideration and a detailed economic and environmental analysis, the Corps concluded that the most effective defense, which would protect the GIWW for a period of approximately 50 years from project completion, requires construction of an armor block revetment.

2.5. Selected Plan

The proposed structure is approximately eight miles in length. The cross section over most of this length consists of a horizontal toe element founded at elevation -10 ft. below mean low tide (MLT), a 1 vertical (V):2.5 horizontal (H) sloping revetment, and a cap section of concrete block as shown in Figure 3. A permanent gravel-surfaced road landward of the revetment section will be incorporated into the project. Foundation conditions require two separate sections, one about 3,000 ft. in length and one about 1,000 ft. in length, to be constructed using 40 ft. long sheet piling as shown in Figure 4. An additional section, approximately 2,800 ft. long, will be built according to the standard cross section except that the revetment will be laid back on a

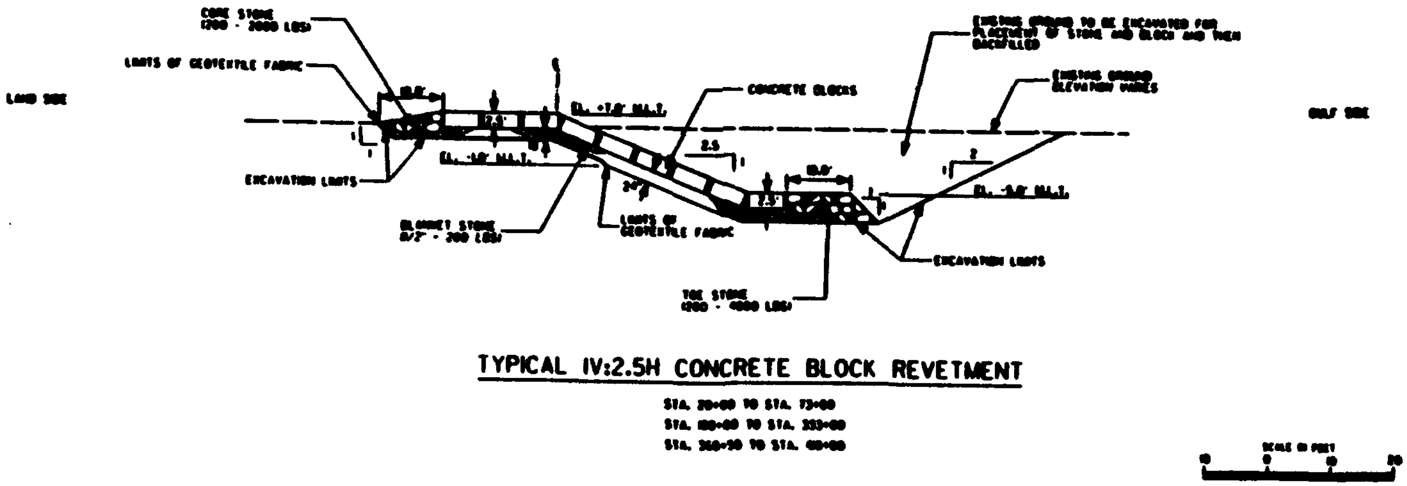


Figure 3. Typical 1V:2.5H Concrete Block Revetment Section

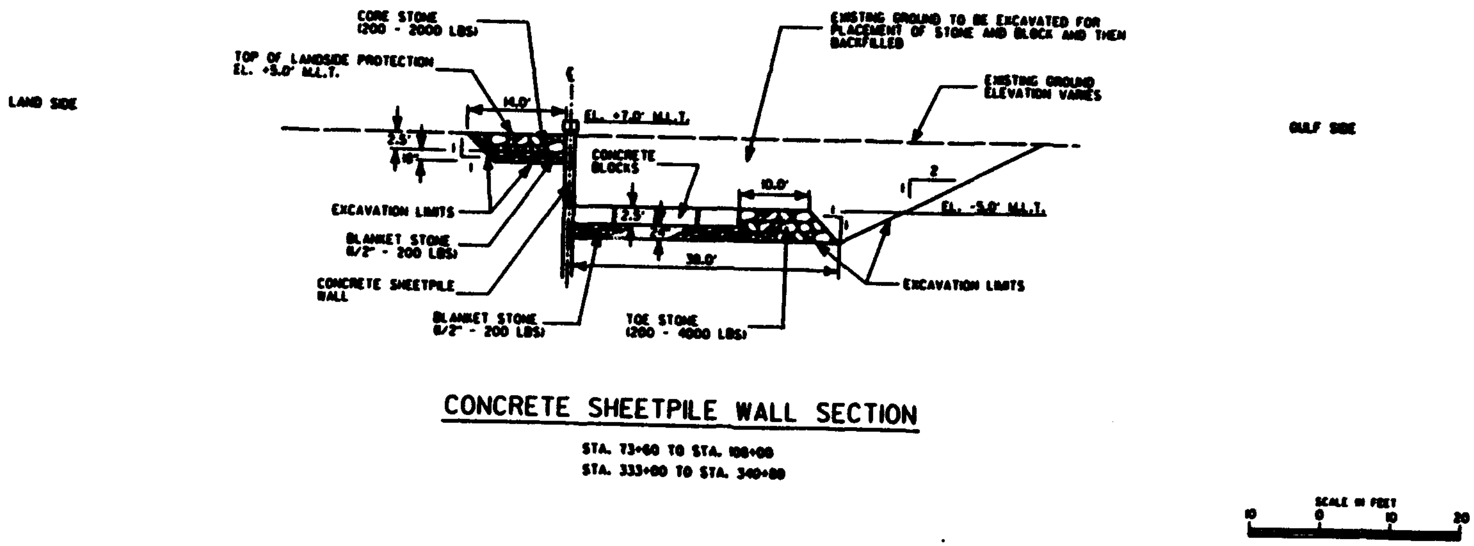


Figure 4. Sheet Pile Wall Section

1V:5H slope and contain a compacted clay backfill base as shown in Figure 5. A plan view breakdown of the structural trace and the locations of the various design cross sections is shown in Appendix A.

The basic construction concept requires excavation to 9.5 ft. below mean low tide and placing the excavated material on the seaward side at a distance sufficient to preclude slope failure. Except for those areas where select material must be placed and compacted, the Corps is agreeable to stone placement under water. Although this makes placement more difficult, it is somewhat fortunate since observed water levels were 2 to 5 ft. above mean sea level in bore holes and any dewatering could prove to be extremely difficult and very costly. A layer of blanket stone, defined as reasonably well graded material ranging in size from 1/2 inch (in.) to 200 pounds (lbs.), is placed against the cut slope. This is capped with 5 3/4 x 5 3/4 x 2 1/2 ft. armor units weighing six tons each. Core stone, which is defined as reasonably well graded material ranging in weight from 200 to 2,000 lbs., is placed at the cap, and material graded from 200 lbs. to 4,000 lbs. is placed at the revetment toe. Following placement of stone, excavated material is backfilled over the toe and the majority of the sloping revetment to restore the area. The revetment and cap rise to an elevation of 7 ft. above mean low tide. Backfilled material must then be replanted for esthetic and erosion protection purposes.

2.6. Project Status

Currently the Corps is pursuing real estate purchasing to permit construction, and envisions purchasing a strip of land 8 miles long and approximately 300 ft. in

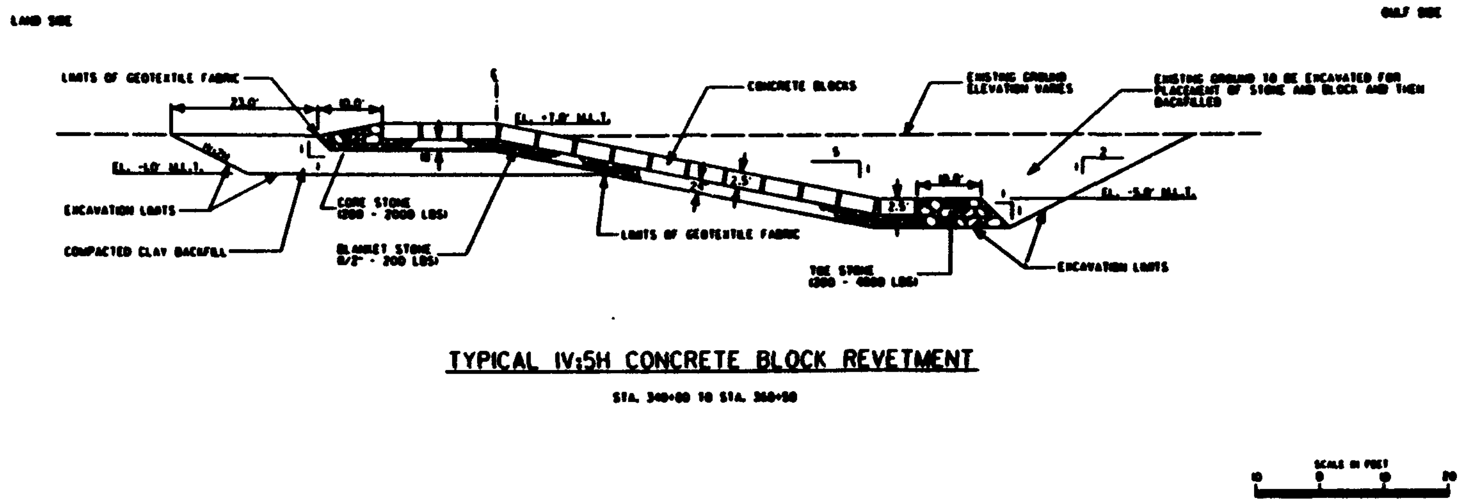


Figure 5. Typical 1V:5H Concrete Block Revetment (Compacted Backfill)

width, along the trace of the structure. The Corps expects to acquire a construction easement on land from the revetment toe to the Gulf for five years to permit conclusion of construction activities. It is estimated that nine vacation dwellings will be acquired, and that additional land acquisition will be necessary for barge terminals and drainage facilities on the GIWW side.

The Texas Department of Transportation is identified as local sponsor for the Sargent Beach Project; however, the Corps feasibility report states that the project will be 100 percent federally funded, partly by inland navigation trust fund money and partly by general appropriations (DA 1992). The project has been authorized formally and funds have been appropriated to commence detailed design. This effort began in March 1993. A fiscal year 1994 construction start is anticipated.

2.7. Corps Feasibility Study

The Corps feasibility report estimates that there will be no construction interference from archeological discoveries or environmental issues. The possibility of storm activity interfering with construction is significant. Historic records show that hurricanes, concentrated in the June through October time frame, occur in this portion of the Gulf of Mexico on an average of once every four years. There is a 10 percent chance of a hurricane striking in the area covered by this project in any given year. Wave analysis shows the possibility of a 3 to 5 ft. high wave breaking over the revetment structure on an average of once in seven years.

At the time the CII study was undertaken, the Sargent Beach Project had progressed significantly. Circumstances at that time were as follows:

a. The feasibility study was complete, to include conceptual design, a preliminary bill of materials, a general trace, and a budget cost estimate.

b. An environmental impact statement had been completed and approved.

c. A local sponsor had been identified and the sponsor's wholehearted commitment obtained.

d. Congressional project authorization had been requested (and was subsequently received shortly after study commencement).

e. Survey cross sections and soil borings had been obtained.

f. A preliminary design of specific project features had been completed.

g. Real estate parcels had been identified and the acquisition effort estimated.

h. Model tests had been conducted at the Waterways Experiment Station to refine coastal engineering design features.

The feasibility study identified time as a critical issue in executing the Sargent Bench Project. The unusually rapid rate of erosion and the possibility of hurricane-induced damage combine to mandate early completion of the protective revetment. Delay in achieving this protection could easily result in a breach of the land between the GIWW and the Gulf shoreline at one or more locations. Should such a breach occur, GIWW traffic would almost certainly be interrupted until completion of emergency dredging and closure of the inlet.

The feasibility study identified national economic development objectives as those to be optimized, clearly signaling the importance of cost in the project plan. The construction option chosen was the one which minimized life cycle cost after consideration of environmental and other constraints. Benefits accrue almost exclusively from GIWW operation, making even more important the uninterrupted use of this facility throughout the construction period and for the next 50 years.

At the time of CII's study execution, Galveston District spokesmen were unaware of significant project opposition. The Governor of Texas has expressed full support for the project and has urged its prompt execution. Members of the Texas delegation in the U.S. Senate are fully supportive, as is the congressman from the district. Local citizens and navigation interests have expressed their support and have urged that the work proceed without delay. The feasibility report says that no local cost sharing will be required for this project. However, the Governor of Texas has indicated that should this situation change, the State Department of Transportation will respond promptly.

Corps of Engineers' design spokesmen have indicated willingness to permit contractor latitude in armor unit design features to facilitate handling, quarry locations, casting yard locations, material surge pile sizes, equipment selection, overland haul techniques, and task sequencing. It is these areas as well as additional material that are addressed in this paper to help enhance the overall project outcome.

3. METHODOLOGY

3.1 Study Methodology

This chapter will discuss the study methodology for conducting this research project. The research data were obtained through a variety of sources in order to ensure comprehensive coverage and these sources are outlined below.

3.2. Solicitation and Organization

Upon agreement between CII and the Galveston District regarding study scope and objectives, appropriate University of Texas faculty members identified graduate students who were interested in participating in the Sargent Beach study as a thesis topic. These students were briefed on the project, given background material to read, and then polled to determine what area of the project they would be most interested in researching.

Once the graduate students committed to participating in the study, the CII Study Director scheduled a coordination meeting in order to organize the research efforts into a logical process. During this initial meeting, a study plan and schedule were established. This planning included identification of potential feasibility topics and the development of a detailed table of contents to facilitate task assignment and author coordination. The study was organized so that, although the research team would work closely together, each participant would be responsible for a specific area or chapter(s). The author of this thesis had responsibility for Chapters 3 (Materials), 4 (Transportation and Handling), and 5 (Work Site Operations) within the constructability study.

3.3. Literature Search

The author utilized several literature sources to help gain insight into the project's background, marine construction methods, and heavy equipment capabilities. Careful review of the feasibility plan, the environmental impact statement, and the study scope of work, provided by the Corps of Engineers, helped the author to develop a comprehensive data collection list. These documents, in conjunction with numerous construction, shore protection, and heavy equipment manuals were used as primary sources of information during the data gathering process.

3.4. Contractor Symposium

A great deal of the information gathered for this study stemmed from a contractors constructability symposium. Construction contractors familiar with coastal engineering works and marine construction in general were identified, partly through review of the CII membership list and partly through analysis of the Galveston District supplied list of active dredging contractors. The CII Study Director independently selected eight representative contractors believed to be skilled in the type of work to be undertaken and willing to share their constructability expertise in open forum. In order to obtain valuable information pertaining to logistical constructability issues, the author developed a comprehensive list of questions to submit for presentation to the contractor's workshop and this is shown in Appendix B. Contractors were invited personally by telephone with letter confirmation. The workshop, which lasted for one day and involved approximately 25 people, was held in a hotel at the Houston Intercontinental Airport in Houston, Texas, on February 12, 1993. An outline of material covered during the session is included in Appendix C.

Contractor receptivity to the format followed in this study and their willingness to participate were unknowns when the study began. However when surveyed, the primary response for attending was that most participants intended to learn more about the project for business development purposes. The next most prevalent motive for attending was to attempt to influence design, thereby making the work more bidable and attractive. Twelve of the 14 contractor representatives present returned the survey and said that if given the opportunity, they would attend a similar workshop for a different project (CII 1993).

3.5. Corps Personnel Contact and Site Visit

Principal administrative contact during project study and report development was maintained between the CII Study Director and the Corps of Engineers Design Project Manager. To help increase communication efficiency, technical contact was authorized directly between the authors and Corps staff experts. CII personnel involved in study production met with Corps of Engineers personnel in the Galveston District office on March 5, 1993 to the discuss the progress of the project and to hear the Corps' viewpoint on selected topics. Following this meeting, CII personnel visited the project site and were given a thorough briefing and tour by the Design Project Manager. Upon request, Corps regulations and policy documents were provided to the study team to assist in the research.

In view of the premium associated with timely completion, and because detailed design progressed concurrently with the constructability study, results of the constructor's workshop and of study team discussions were communicated early in verbal or draft form to the Design Project Manager. Certain issues highlighted in these preliminary reports were studied in-depth by responsible design officials in the District office, and in several cases further design analysis resulted.

3.6. Interviews

Several telephone and personal interviews were conducted with selected contractor representatives, stone and concrete suppliers, and heavy equipment specialists to obtain logistical information needed for the research study. In addition, data pertaining to the GIWW and other navigable waterways, including the Mississippi River, were gathered from Corps offices other than the Galveston District. The author also gathered valuable information on material options and quarry operations during a site visit tour to a local stone quarry.

3.7. Study Direction and Coordination

The Study Director maintained contact with the Design Project Manager, keeping him abreast of project status and providing early notice of probable recommendations. The graduate student authors met with the study director every two weeks to insure coordination, discuss progress, and establish goals for the next production period. The Study Director is also serving as second reader for this masters degree thesis.

3.8. Data Analysis

An analysis of the research data gathered is based on achieving project objectives. Because the data were obtained through people with construction knowledge and experience, the recommendations and conclusions resulting from the data analysis should help to enhance the overall project success.

The following three chapters present the data obtained during the author's research investigation. The material in these chapters is based on standard references, participating contractor opinions, material supplier response to inquiries, conceptual level design decisions, and reasonable assumptions injected by the constructability study team. Although care has been taken in making assumptions, specific conclusions as to project quantities, equipment required, time required for scheduled tasks, job execution strategy, and likely costs should be taken as examples only for the sake of testing general project feasibility.

4. MATERIALS

4.1. Summary of Requirements

The Sargent Beach Project is resource intensive. The materials selected for the erosion control structure play an important role in achieving overall project objectives. The costs associated with the effort as well as the construction methods used during construction are directly related to the material types and quantities chosen for the structure.

Eight categories of materials are required for the erosion control structure and are shown in Table 1 below. Seven of the categories are unavailable at the project location and must be obtained off site. The eighth category is the in-situ material on the island that needs to be excavated prior to construction. The table also provides estimates for the total quantities required throughout the project's duration.

Table 1. Categories of Materials Required for the Erosion Control Structure

Number	Category	Units	Quantity
1.	Blanket Stone	Cubic Yards (CY)	156,938
2.	Toe Stone	Cubic Yards (CY)	85,550
3.	Core Stone	Cubic Yards (CY)	34,798
4.	Armor Units	Each (Ea)	68,345
5.	Sheet Piles	Each (Ea)	2,110
6.	Compacted Clay	Cubic Yards (CY)	26,370
7.	Geotextile	Square Feet (SF)	1,445,413
8.	Excavation	Cubic Yards (CY)	1,025,098

These estimates are material takeoffs based strictly on the preliminary design information and do not incorporate any CII constructability suggestions. In addition, the estimates do not include materials needed in the construction of mooring facilities, access haul road, drainage ditch, transition sections, or the end sections.

4.2. Material Selection Factors

When selecting the materials most appropriate for an erosion control structure, there are several factors which must be considered. The most obvious factors requiring attention during the selection process are costs, availability, strength, and size/specific gravity.

The costs associated with the procurement of materials are usually somewhat competitive and should not significantly vary from one supplier to the next. However, because of limited access to Sargent Beach and the quantity of materials to be hauled, transportation costs become an influencing factor in material selection.

The primary materials required for the structure are quarry stone, armor blocks, and sheet piles. Fortunately, quarry and precast materials are readily available throughout Texas as well as from most areas in the continental United States.

The materials used on the project must be able to withstand the severity of the coastal environment. The quarry stone used for this project should be sound, durable, and hard. It should be free from laminations and weak cleavages and should not disintegrate from the action of undesirable weathering or during handling. Likewise, concrete structures should possess the ability to resist weathering action, chemical attack, abrasion or any other process of deterioration. It is imperative that the materials selected are capable of maintaining their strength and durability throughout the desired lifespan of the structure.

The specific gravity of the materials can help decrease the volume of material required in the structure as well as increase the resistance to movement due to wave action. High specific-gravity materials are essential when constructing a submerged structure.

4.3. Material Options

Although there are several classifications of stone which could be used for the blanket stone, core stone, and toe stone, the primary three are granite, limestone, and dolomite. The most feasible material options for the six ton armor units are granite and precast concrete. The following subsections will address these options and provide some of their important characteristics.

4.3.1. Blanket, Core, and Toe Stone

Granite is a medium-to-coarse grained igneous rock which is extremely dense and impervious to water (porosity of less than one percent). Granitic stones are hard, strong, and resistant to abrasion, impact, and chemical attack. The average unit weights range from 155 to 175 pounds per cubic foot (lb/ft^3), which is nearly 10 percent heavier than limestone (Hockney and Whiteneck 1989). Although granite is probably the most effective type of material for marine structures, it is far more expensive to produce than other alternatives. Typically, hard rock costs 15 to 20 percent more than the softer carbonate stone (ASCE 1992). Therefore, although it remains a bid alternative, granite probably will not be able to compete with the carbonate stones for use as blanket, core, and toe stone.

Limestone contains a high percentage of calcium carbonate and has a porosity range from one to 15 percent. The average unit weight of limestone ranges from 140 to 165 lb/ft^3. In order to be effective, it should be physically sound, durable, and relatively pure (Hockney and Whiteneck 1989).

Dolomite is a carbonate stone, similar to limestone, and consists mainly of the mineral dolomite. It is tough, strong, and durable and is well suited for use as riprap, armor stone, or underlying rock layers. Several projects in the Southeastern U.S. and Gulf Coast region have successfully relied upon this type of material (CII 1993).

4.3.2. Armor Units

Because of the enormous size and weight requirements needed to effectively control the erosion process, the options available for the armor units are reduced to precast concrete and quarried granite. The specified dimensions (5-3/4 ft x 5-3/4 ft x 2-1/2 ft) and designated weight (six tons) were found to be most effective during testing at the Waterways Experiment Station, Vicksburg, Mississippi. The shape and weight of armor stone provide the stability needed to undergo constant wave action, while the revetment's design and flexibility allow for the relief of hydrostatic uplift pressure and minor consolidation or settlement without structural failure. The use of quarried rock in a "rubble effect" was eliminated because of the high probability of wave action moving or damaging the protective structure.

Concrete has became one of the most widely used materials in the construction of marine structures for several reasons. It provides excellent resistance to water, can be formed into specified shapes and sizes, and can be obtained almost anywhere in the world at a reasonable price. The most appropriate protection is provided by a dense concrete mix with minimal porosity. This helps provide strength against impact and limits the opportunities for water to collect or for salt solutions to penetrate beneath the surface.

The contractors at the CII symposium felt the precast concrete armor blocks should have a minimum recommended strength of 3500 psi and should contain sulfate resistant cement if the structure is exposed to a high sulfate concentration of sea water (CII 1993).

In addition to sulfate-resistant cements, the use of blended cements can work effectively. Type IP contains up to 30 percent low-calcium fly ash and has been proven effective from the standpoint of durability (Mehta 1991). The use of admixtures can also enhance the property characteristics of concrete by improving the workability, impermeability, and resistance to thermal cracking.

The armor unit specifications should be of standard design with no exotic cement requirements. The contractors at the symposium recommended that the aggregate used should be commercially available, preferably the standard two inches and below. The concrete should have hard stone to help prevent possible erosion. Crushed limestone should be sufficient aggregate for the concrete armor blocks.

Granite, the second material option for the armor units, is perhaps the most durable quarried stone available for marine structures. Unfortunately, the specifications set forth dimensional criteria which are often difficult to maintain, and a great deal of stone is wasted due to irregular breaking from latent cracks or seams. The cost in stones that are rejected can become quite expensive which, in turn, results in increased bid prices. Another factor which increases the price of quarried stone for armor unit use is the relatively low percentage yield from most quarries (i.e., only 5% of a particular quarries' production may be the required four to six tons). Therefore, it is sometimes necessary for quarries to alter current operations and obtain additional equipment to assist in handling the increased size and volume of material. For these reasons, the granite alternative will probably not be able to compete against the precast concrete option. However, as long as it can meet the prescribed specifications, it should remain a valid option with the final decision left to the construction contractor.

4.4. Sheet Pile Wall

Perhaps the most controversial parts of the entire project are the sheet pile wall sections. The majority of the contractors attending the CII constructability symposium expressed considerable concern about the stability of the current sheet pile wall design. They believe that the cantilevered wall would most likely fail without the use of tiebacks. The load created by the in-situ material from the GIWW side combined with the surcharge imposed by necessary construction equipment makes it very important to confirm slope and pile wall stability as part of a pre-bid demonstration.

Several contractors felt the wall would prove to be quite costly and that another method or design might be more feasible. One contractor estimated that the use of concrete sheet piling could conceivably increase the overall project cost by two million dollars (CII 1993).

The three most feasible options discussed were: 1) eliminate the sheet pile wall entirely and replace it with a modified revetment design, 2) replace concrete sheet pile with steel sheet pile, or 3) alter the design of the concrete sheet pile so that tiebacks or other structural reinforcement are included. These options are addressed in the following subsections. The use of slurry wall was also mentioned, but it was eliminated as an infeasible alternative.

4.4.1. Sheet Pile Wall Elimination

The general consensus at the CII symposium was to completely eliminate the sheet pile wall. One alternative was to modify the revetment design by decreasing the slope and increasing the amount of stone. In addition, strengthening of the soil in the areas of poor foundation conditions could be achieved through the use of geotextile fabrics. Although, the material cost for the increased stone may exceed the cost of the concrete sheet piles, it might still be less expensive to use the modified revetment. This is because contractors are likely to include substantial contingency fees for the risks they anticipate in building to tight specifications in an area of uncertain stability.

4.4.2. Steel Sheet Piles

Replacing concrete sheet piles with steel sheet piles may decrease the life expectancy of the structure. The advantages in handling and driving the steel piles, however, could dictate their use. Steel sheet piles are robust, relatively easy to handle, and are capable of being driven hard to a deep penetration. The steel sheet pile wall forms a rigid, continuous, and earth-tight structure that restricts the passage of water to minimal amounts. This condition can be held for any depth that the sheet piling can be driven (USS 1983).

The Corps has expressed some concern over whether steel can withstand the harsh marine environment for the structure's 50-year life expectancy. In marine environments, examination of carbon steel performance in the splash zone, the most critical zone in sea water service, reveals that the corrosion rate is several magnitudes in excess of either the atmospheric or immersed zones (Tomlinson 1977). There are, however, several protective measures that can prolong the steel's life expectancy. Paint coatings followed by the application of coal-tar epoxy can be easily accomplished at the manufacturer's site. Cathodic protection is another method of prolonging the life of a steel structure in a marine environment. However, this method is most effective for the section of steel which is continuously immersed in salt water (ASCE 1984). Perhaps the most effective alternative when using steel sheet piles is to use a corrosion-resistant steel along with a protective coating and cathodic protection (Hockney and Whiteneck 1989). By using continual maintenance through periodic cleaning and painting and the steel sheet pile should remain structurally efficient for the life of the structure. The contractors at the CII symposium noted several projects where steel sheet piles have been subjected to a marine environment for 40 to 50 years and are still effective.

4.4.3. Concrete Sheet Piles

Although concrete sheet piles could also be attacked by various chemicals found in sea water, they are generally not susceptible to environmental deterioration if made of high quality, dense concrete and if reasonable precautions are taken to ensure that the concrete is undamaged during installation. One of the principal problems associated with precast concrete is unseen breakage due to hard driving conditions. The strength of the concrete should be a minimum of 5000 psi, and if exposed to a high sulfate concentration, then a sulfate resistant cement along with a protective coating on the reinforcement should be used.

4.4.4. Specifications

Because contractors attending the symposium lacked confidence in the sheet pile wall design, they expressed a preference for procedural specifications. They felt that this would reduce their risk. If performance specifications are going to be employed, they felt a test pile demonstration would help eliminate some of the uncertainties during bid preparation. It was also noted that if performance specifications are utilized, then the contractor should have the authority to utilize whatever means or methods he deems necessary to successfully accomplish the job, including the use of tiebacks.

4.4.5. Pile Cap

In order to spread the load from a single pile onto a group of piles so that loads are equally distributed, a concrete pile cap is constructed in a way which interconnects several or all of the piles within the wall section. The cap also provides a means of controlling severe deviations from the piles intended position. By rigidly connecting several piles into a uniform group, the ill-effects of one pile can be overcome by the remainder of the group.

When the contractors considered pile cap options, the consensus was that a precast pile cap is much cheaper and that installation would be less time consuming. However, if the design specifies that a cast-in-place concrete pile cap should be used, the consensus was to establish a batch plant on the island or on a barge so that the concrete source was readily available.

4.5. Geotextile

Geotextiles are constructed of synthetic fibers which assist in the filtering and separation of materials as well as providing additional reinforcement for soils. The filter is used to prevent the mixing of materials that should remain apart, such as the poor subgrade soil currently existing on Sargent Beach and the good subgrade material used for the blanket stone. It also is used to replace all or part of a conventional filter system consisting of one or more layers of granular material. The filter must be permeable in order to relieve the hydrostatic uplift pressure, should have the durability necessary to withstand dynamic forces, and should have the puncture resistance to survive placement of other materials.

The contractors at the symposium felt that in extremely weak soil conditions a geotextile fabric is less expensive and more easily installed, and therefore is preferred over other methods of soil stabilization such as lime or cement. The fabric is available in various compositions and can usually be purchased as a standard off-the-shelf item. The widths generally vary between 6-18 feet and can be sewn, bonded, or lapped to form wider sections (DA 1986). For simplicity, the contractors prefer lapping. The consensus at the constructability symposium was to consider using a geotextile fabric throughout the entire cross section of the revetment structure. It is relatively inexpensive and the time expended for placement is negligible, especially when compared to the benefits likely to be attained through its use.

Geotextile fabric for this project should not require a great deal of lead time for procurement. The material generally comes on a large spool and can be transported and placed easily. The final decision on which type of geotextile to use should be based on the existing soil conditions and the filter characteristics needed to prevent penetration of fine materials into layers of coarser material.

4.6 Locations Studied and Results by Material Type

The enormous logistical requirements incident to this project make it necessary to identify the potential material sources as early in the planning process as possible. The location and capabilities of potential sources can have a significant impact on the project's budget and schedule. By eliminating the number of uncertainties during the planning phase, it becomes far easier to estimate the project's outcome. In order to determine the most attractive material sources for this project, numerous contractors, equipment and material suppliers, and owner representatives were queried.

The required blanket stone, core stone, and toe stone can all be obtained from a single supplier. Procurement from a source relatively close to the construction site helps to reduce transportation costs significantly. Fortunately, several quarries within Texas can fulfill project needs. In addition, quarries along the Mississippi, Ohio, and Arkansas Rivers are feasible alternatives.

The following subsections discuss the stone and granite quarries which are the most likely alternatives to provide the material requirements for the Sargent Beach Project. In addition, the armor unit and sheet pile precast yard alternatives are addressed.

4.6.1. Stone Quarries

The stone quarries within Texas are generally located along the Balcones fault zone of the Edwards Plateau in Central Texas. Crushed stone from these quarries is predominantly limestone with a unit weight of 150 lb/ft^3 (Isbell 1993). Unfortunately, there is no navigable waterway for transportation to the job site. Therefore, truck or rail must be used to haul material to the nearest port location. From there the material can be loaded on to barges for further transport. This process involves double handling the material, which, in turn, will increase the cost. Quarry operators said there should be no significant problem in producing the required stone sizes and gradation. They can provide a minimum of 5,000 tons per week. These sources say they have been providing crushed stone for marine structures for more than 50 years with relatively few problems or complaints (Isbell 1993).

The quarries located along the Mississippi, Ohio, and Arkansas Rivers, although much further away, could have a significant advantage since each has easy access to a navigable waterway. The majority of the quarries are located directly on a waterway and are capable of loading barges directly from their production lines or storage locations. (Actual loading and transport will be addressed in Chapter 5, Transportation and Handling.) The rock produced at these sites is from the Salem and Plattin geological formations and is predominantly dolomitic or calcinic. The specific gravity of the stone is between 2.56 and 2.65, with a unit weight of 159 lb/ft^3 to 166 lb/ft^3. The quarries located near St. Genevieve and Cape Girardeau, Missouri are capable of producing over 60 product sizes, and on any one day, produce 18 sizes concurrently (TRS 1993). Numerous quarries along these rivers can provide the sizes and quantities of stone required for this project. Several of them currently provide large volumes of stone for similar projects along the Texas and Louisiana coasts.

A critical issue when evaluating a potential quarry is the percentage of heavy blocks it yields. While some quarries may yield 30 to 40 percent heavy blocks, others might only yield 5 to 10 percent. It is possible to modify the yield ratio somewhat by specialized blasting and careful handling. However, it is extremely difficult to change t' · overall long-term yield pattern (ASCE 1992). By performing yield and cost comparisons, it is relatively easy to determine which quarries can supply the stone needed. Those quarries which must alter their operations drastically to meet size and quantity requirements will probably charge higher prices. The average price of riprap at the larger, well established quarries is estimated to be $7-$8 per ton, excluding transportation and handling costs (Isbell 1993).

Because most quarries can deliver stone within the limits specified, the issue of gradation has not been a significant concern. However, how the quarries choose to grade their stone can affect price. The larger the stone, the less susceptible it is to screen or grizzly separation. Very large stone must be separated at the quarry face with excavating equipment. At many sites, the larger stones are individually weighed and then stockpiled. An experienced operator can select and sort the stone at a lower cost. This is a skilled task because the weight and size proportions are seldom directly related. The size difference between a two-ton rock and a four-ton rock is only about 25 percent (ASCE 1992). Fortunately, several of the larger quarries have experienced operators and mechanical screening devices capable of separating two- to four-ton stone.

In order to ensure that stone gradation is within the required specifications, visual inspections should be carried out at the quarry location. The on-site inspector should be afforded the opportunity to visually inspect an established pile of stone with the desired gradation. The pile of stone should be of sufficient size to provide an adequate representation for the inspector. In addition to reviewing gradation, the inspector should require laboratory tests for evaluating the stone. Petrographic analysis, specific gravity, absorption, and abrasion are standard tests at most quarries, and records should be available to show that the stone is satisfactory (ASCE 1992).

The different sizes of rock required for the blanket stone, core stone, and toe stone increase the logistical requirements for producing, stockpiling, handling, and placing. Each classification of stone requires separate handling and storage, which, in turn, increases the overall cost of the project. Consideration should be given to reducing the number of classifications. Such consideration could lead to installed cost reduction.

4.6.2. Granite Quarries

The best source of granite for this project is located in Central Texas (in the vicinity of Marble Falls, Texas). There are numerous quarries which produce granite from a Precambrian formation of rocks known as the Llano Uplift. Stone from this location was used for the Galveston seawall and many of the jetties along the Gulf Coast of Texas and Louisiana. Granite blocks produced in this location usually range in weight from four to six tons. However, it is possible to produce much larger sizes (ASCE 1992). The granite producing quarries perform the same standard tests as those required for blanket, core, and toe stone. Once again, a visual inspection is recommended at the quarry site to ensure that the rock meets the size and test requirements specified in the contract documents. The armor unit's size and shape specifications may significantly increase the cost of producing granite blocks. This is due to the precision drilling and blasting the stone must undergo to satisfy the requirements as well as the careful handling that must take place to prevent secondary cracking.

4.6.3. Precast Concrete Armor Units

Although granite is a viable alternative, precast concrete blocks are the preferred option for six-ton armor units. The majority of the contractors attending the CII constructability symposium felt precast concrete was the most likely choice for use as armor units (CII 1993). Although, initially, there was no consensus as to whether the contractor would set up a casting yard or use an existing precast plant as a supplier, subsequent conversations revealed that the majority of the large contractors would establish their own batch plants. The costs associated with precasting the concrete blocks is somewhat comparable wherever they are produced. Therefore, transportation cost is the deciding factor in whether a contractor should establish a casting yard or use an existing supplier.

Throughout the State of Texas there are numerous quantities of existing suppliers for precast concrete. However, because transportation cost is an important criterion in selecting precast suppliers, only those plants with access to a navigable waterway were considered. The contractors agreed that the only economical means of transporting the precast armor units would be by barge. Therefore, if an existing supplier is used, it is most likely it would be located in the vicinity of an existing port, such as Freeport or Houston. Unfortunately, although several precast yards do operate in these cities, few are located in an area with access to a navigable waterway.

Because of the lack of precast yards with access to a navigable waterway, the contractors felt they could reduce the cost of transportation and multiple handling by establishing their own batch plants in an area with waterway access. Fortunately, several of the larger contractors already own property in the Houston or Freeport areas, which are adjacent to a waterway and should have relatively few problems establishing a plant capable of manufacturing precast armor units. Those contractors that do not own property will most likely lease a plot of land large enough to establish a precast yard that also provides access to a navigable waterway.

The precast yard must be designed to produce up to 250 blocks per day, with the final number to be determined based upon the contractor's adopted method of operation. During production, it is essential that a provision for lifting be incorporated into the concrete block design so that the blocks can be handled and placed easily. The various types of lifting devices will be discussed in Chapter 5, Transportation and Handling. Since it is important that the concrete blocks are well cured before placement, a substantial storage area must be nearby. The longer the concrete has to cure, the less susceptible it is to damage during handling and transport. The time that the precast concrete must cure before being moved should be left to the contractor's discretion. The consensus at the CII symposium was that the contractors prefer performance specifications to provide maximum flexibility to use new techniques (CII 1993). In other words, the contractors want to know what the blocks should look like and any other mandatory design requirements and then they can determine the details on how to construct and move the armor units.

Since the majority of the blocks will be buried, finishing or texturing on the blocks should not be required. However, special block sizes may be needed in transition areas adjacent to sheet pile sections and possibly at times when closing gaps between two work faces. This should be relatively easy to accomplish if the precast yard is operated by the same contractor who is performing the construction.

The aggregates used in the concrete blocks should consist of clean sand, river-washed gravel, or crushed rock. There are large deposits of adequate sand and gravel in many places along the Colorado River in Texas. Commercial aggregate is readily available in Victoria, Eagle Lake, and Columbus, Texas (DA 1992). The aggregate from these sources has been used for many years and has an excellent performance record. The existing plants in Houston and Freeport rely on these sources as well for their aggregates, and likewise have had a great deal of success. If desired, additional admixtures and superplasticisers are commercially available throughout the State of Texas.

4.6.4. Concrete Sheet Piles

Because of the reinforcement and pretensioning requirements in the concrete sheet piles, the contractors will most likely choose an outside supplier. Relatively few concrete plants are located along a navigable waterway. However, the sheet pile quantity requirements are low enough to justify using an established supplier.

When pretensioning concrete sheet piles, adequate beds must be available to maintain the tensioning forces and pile alignment as the concrete cures. A sheet pile supplier in the Corpus Christi, Texas, vicinity has the beds available to produce 10 sheet piles per day, five days of the week (Gentry 1993). If this production rate fails to meet the placement rate of the sheet pile, then the construction contractor must stockpile an adequate quantity of sheet pile or the supplier must expand the precast facility so that the demand can be met. This supplier also has ready access to the GIWW and is capable of loading barges directly from a production yard. The supplier must construct the piles with dense, impermeable concrete in order to prevent chloride (sea water) from attacking the reinforcing steel. The specifications regarding reinforcing steel covering depth is critical and should be addressed in the contract so that there is an adequate amount for life expectancy of the structure. The use of sulfate resistant Portland cement should be required for the concrete piles (FIP 1986).

It is essential that the supplier clearly mark the lifting and support points on the pile so that proper lifting techniques can be used during handling and transportation. Lifting inserts should be incorporated into the design as discussed in more detail in Chapter 5. This will help to eliminate damage incurred during transport and placement.

5. TRANSPORTATION AND HANDLING

5.1. Production Site Handling

The handling of materials at the production site, which is the initial step in the transportation process, can have a significant impact on material quality as well as overall transportation cost. The variety of equipment found on a production site differs from one location to the next, depending on the size and quantity of the materials produced. The objective at any site, once the material has been produced, is to minimize the amount of handling and work effort involved in preparing the material for transport. Excessive handling can cause unnecessary damage and degradation. This, in turn, will increase the material's rejection rate and eventually lead to higher costs. The following subsections will address the handling procedures used at stone quarries as well as the design requirements needed when handling concrete.

5.1.1. Production Quarry Site Equipment

The quarry sites located along the Mississippi, Ohio, and Arkansas Rivers are capable of loading their materials directly from their production yards on to the barges that will transport them. Once the material has been mechanically separated, the smaller blanket stone will be loaded into dump trucks with a backhoe excavator, front loading shovel, or some form of mechanical hopper. The trucks will then dump the material directly on to the barge specified for blanket stone. The larger core and toe stone, however, must be placed on barges with cranes or large front-end loaders in order to prevent damage to the barge plank as well as secondary cracking to the rock

(TRS 1993). This proves to be a bit more time consuming, but is still relatively quick when compared with the overall transport time.

The quarries located throughout Texas do not have the luxury of a navigable waterway adjacent to their site and, therefore, will be loading their stone on to trucks or rail cars. Once again, the majority of the materials will be loaded with excavators and/or front loading shovels, depending on size. A typical 100-ton gondola car can be loaded with a standard five-cubic yard bucket in less than 10 minutes. In some cases, a conveyor system is capable of transporting and loading the blanket stone. The core and toe stone, however, is much too large. For those quarries which are not equipped with mechanical gradation devices large enough to handle core and toe stone, a front-end loader will be used to selectively separate the various sizes. Some quarries use front-end loaders that have a weighing device incorporated into the bucket along with a meter for the operator. This helps provide the accuracy needed to correctly separate and stockpile the larger stones.

Quarried granite blocks are extremely heavy and somewhat difficult to move. Although a front-end loader is capable of lifting one or two armor units simultaneously, a crane with a rock grapple, orange peel or specially designed attachment can lift and position the blocks far more effectively. The quarries located throughout Texas will probably load the granite blocks on to flatbed rail cars for transport to the nearest port. Because of the armor unit's enormous weight, only 12 to 15 blocks can be loaded into the flatbed. This should require one crane with an experienced operator for no more than 10 to 12 minutes (Isbell 1993). Loading the armor blocks onto barges will take considerably more time and will depend on available loading equipment at the port facility.

5.1.2. Concrete Requirements

Precast concrete is highly susceptible to damage during handling and transport. Therefore, it is critical that the concrete be allowed sufficient time to cure prior to movement. Once the concrete has acquired its necessary strength for movement, then the blocks or piles can be moved to a storage location where they will continue the curing process and await further transport. Fortunately, several of the established precast yards are equipped with an overhead crane system that can rapidly transport and load concrete armor units and sheet piles. Those yards not equipped with such facilities must use large forklifts, cranes or other alternative methods when handling the armor blocks and sheet piles.

In order to effectively handle the concrete units, lifting inserts and support points should be agreed upon by the Corps as well as the contractor. Otherwise, the contractor may designate a lifting device that, although advantageous for transport and placement, might have a negative impact on future maintenance operations. The best approach is probably to allow the contractor to develop a particular method, subject to Corps approval, rather than have the Corps dictate by means of block design or through procedural specifications the method to be used. Although the type of lifting device selected is not a critical issue for handling at the production site, it will prove to be critical during placement and follow-on maintenance operations. The lifting device should, therefore, be incorporated into the design and tested at the manufacturing site. The following alternatives are available when considering the most appropriate lifting device:

a. Lifting Eye. This is perhaps the easiest means of lifting and placing the concrete units. However, eventual corrosion will not allow for lifting the unit during subsequent maintenance operations.

b. Wire Loops. This is an effective method for placing the concrete blocks, but is also subject to severe corrosion.

c. PVC Pipe. By casting a hole all the way through the side of the concrete block with a PVC pipe, the contractor can place the unit with relative ease, yet still allow subsequent operations to take place.

d. Innovative Top Lift Mechanism. The most advantageous lifting device lifts the blocks from the top and not from the sides. If the block is lifted from the sides, it will be extremely difficult to place underwater within the specified tolerance. Given the large quantity of blocks to be placed, a contractor's ingenuity in devising an efficient method of handling the blocks has the potential to pay large dividends.

Concrete and steel sheet piles should also have sufficient pickup and support points to prevent permanent cracking or deformation of the piles. Lifting and blocking points are predesignated so that bending stresses will be within acceptable limits. When handling the piles at the production site, slings should be positioned so that no excessive concentration of weight occurs at any one point. This can be easily accomplished with an overhead crane system or a standard crane with a sling device. When piles are stored or transported, they should be on a level surface. Blocking should be spaced at distances sufficiently short to prevent excessive sag.

When lifting a single piece of sheet piling from one end, caution must be exercised so as not to bend the sheet and cause permanent set. This becomes important on longer lengths where the bending forces are more apt to cause damage. Steel sheet piles are often furnished with one handling hole at one end of the web, while concrete piles use wire-loop lifting inserts in the ends or sides of the panel. The most severe bending stresses occur when the piles are lifted from their horizontal position for transport and placement. Since reinforced concrete piles generally have a relatively low resistance to bending, stresses caused during lifting may dictate the amount of longitudinal reinforcing steel needed. In order to reduce the bending moments induced by lifting, which in turn will reduce the amount of reinforcement needed, the location of the lifting inserts should be investigated so that the lowest possible stresses are placed on the pile during lifting. Depending on the size and shape of the pile, the lifting inserts might be placed at any point between the middle and the end.

5.2 Production Site to Job Site Transportation

Most construction materials for coastal projects are transported to the project site by conventional freight, such as rail, truck, or barge. Unfortunately, access to Sargent Beach, Texas, is extremely limited and the only feasible method to get heavy materials on to the island is by barge transport. Although an existing swing bridge does provide access to the island for some vehicular traffic, its 26-ton carrying capacity is by no means adequate for the transport of heavy materials. In addition, when the bridge is employed, it interferes with traffic on the GIWW. Therefore, any use of the swing bridge will be limited to small vehicles carrying personnel and light equipment. The following three subsections provide a more detailed explanation concerning the most feasible methods for transporting materials to the island.

5.2.1. Barge Transport

The blanket, core and toe stone that originates from quarries along the Mississippi, Ohio and Arkansas Rivers can be transported directly from the quarry site to the island with the use of barges. The quarries have ready access to a navigable waterway that eventually connects with the GIWW. The quarries are capable of loading stone on to the barges once it has been mechanically separated.

The barges used to haul the stone vary in size and have hauling capacities ranging from 300 to 5,000 tons. When transporting crushed stone, however, the majority of the barges used will haul approximately 1,500 tons, require a 9-foot draft, and have an average dimension of 35 feet by 195 feet. Depending on the size and type of barge used (i.e., flat deck or hopper/gondola), the average rental rates range from $150 to $275 per day (White 1993). Typically, the barges will form a large line formation consisting of approximately 30 barges while traveling down the Mississippi River. However, once the tow reaches the GIWW, the barges must be reconfigured into rafts consisting of no more than six barges (White 1993).

The total distance traveled from Cape Girardeau, Missouri, to Sargent Beach, Texas, is approximately 1,350 miles. St. Genevieve, Missouri, is an additional 55 to 65 miles north. The barge tows average between 3-1/2 to 5 miles per hour throughout the entire trip (excluding locks along the GIWW). Therefore, it takes anywhere from 12 to 17 days to transport cargo from these locations to the island. This, in turn, results in an estimated transportation cost of $2.00 per ton. Unfortunately, the cost of towing the barges (tug expense) is not included in this estimate and will significantly increase the overall transportation cost. The towing expenses can be negotiated through a brokerage company and will depend on the quantity of material and the distances traveled.

Periodically, barge traffic encounters weather related problems that impedes progress. Ice is probably the most severe problem in that it can stop operations completely. Fortunately, this seldom occurs, and it has been several years since the Mississippi River has been closed for this reason. Both high and low water levels can also affect barge traffic as has occurred this past summer. Low water levels affect allowable barge draft and restrict the amount of cargo a barge is permitted to carry. High water levels, on the other hand, cause problems at the ports while attempting to load cargo. Finally, the weather phenomenon that occurs most often and causes the most delays is fog. Heavy fog rarely stops traffic, but is capable of slowing traffic considerably. Traffic may also cause minor delays. Historically, the months with the least amount of traffic are March, April, and May, whereas the months most traveled are August, September, and October (Patton 1993). The contractors at the constructability symposium felt there were normally no significant complications in moving materials from the source location to the barge terminal. The suppliers are generally reliable and deliver large quantities of stone to this area (Gulf region) on a regular basis.

5.2.2. Rail or Truck Transport

If the blanket, core, and toe stone should happen to be produced from the quarries located in Central Texas, then the mode of transportation must either be rail or truck. Because of the massive quantities of stone which must be hauled, however, the truck option could prove to be extremely expensive and is, therefore, unlikely. It is fortunate that several of the larger quarries have a railroad spur that merges with a statewide rail network. The distance from the quarries located along the Balcones fault zone to Sargent Beach is nearly 200 miles. It should take no longer than 24 hours for the cargo to arrive at a port where the stone can be transferred to barges. Although the distance is significantly less than those quarries mentioned above, the estimated transportation cost ranges from $6 to $8 per ton (Isbell 1993). This estimate does not include the additional handling expense when transferring the material, nor does it include barge and tow expenses necessary for transporting the material to the island. It is apparent that the geographic implications of potential rock sources is somewhat unclear. Once all transportation costs have been analyzed, a 1,300- to 1,400-mile barge tow could prove to be cheaper than a 200 mile rail or truck haul. To determine the most likely material source location, a feasibility analysis should be conducted using the cost data from all aspects of the various transportation alternatives (i.e., barge rental, rail cost, transfer fees, tow expenses, etc.).

5.2.3. Transporting Precast Concrete

By establishing a precast concrete yard along the GIWW or another navigable waterway that merges with the GIWW, the contractor can eliminate unnecessary expenses associated with double handling and excessive transport. The best potential site for a precast yard is in a location that has existing docking and loading facilities. This would prevent the contractor from having to construct these facilities prior to beginning production. Houston, Freeport, Galveston and Corpus Christi, Texas, are good potential locations for the contractor to establish a casting yard. Several of the larger contractors already own property in these vicinities, and additional leasing would not be necessary. The estimated travel time from Houston to Sargent Beach for a six-barge raft is 20 to 24 hours. Therefore, the average cost for transporting concrete armor units from Houston, or any other location with approximately the same travel distance, is $0.17 per ton or about $1.00 per block. Once again, this estimate only includes barge rental costs; by including towing expenses the overall transportation cost would increase significantly.

Hauling could also prove to be extremely difficult if truck or rail is used. The highway weight limitation imposed by the Texas Department of Transportation is 40 tons. Therefore, a tractor trailer rig weighing 15 tons is only capable of hauling two sheet piles (weighing about 11 tons each) or four armor units over public roads. Likewise, a 100-ton flatbed rail car can transport only eight or nine sheet piles, or up to 15 or 16 armor units.

The relatively low cost of transporting the blocks and piles a short distance by barge is the primary reason contractors feel it is more feasible to establish or use a batch plant on the mainland as opposed to the island. The costs associated with transporting, unloading and establishing a batch plant on the island, along with the costs of hauling in all the aggregate and other materials needed for the concrete, far exceeds the expense of hauling only armor blocks or sheet piles.

If a precast yard is not established and an existing supplier is selected or the armor units come from a granite quarry, then the transportation costs should be somewhat similar to those described in Section 5.2.2. The entire expense of transporting by rail or truck, in conjunction with the additional costs associated with double handling the blocks so that they can be loaded on to a barge for final transport, makes these options nearly infeasible. The only possibility that would make these alternatives feasible is if the rail line or truck company can provide the contractor a competitive rate.

5.3. Job Site Off Loading

Once the material arrives at the island, it is essential that it is handled in the proper fashion. The number and size of the mooring facilities used to facilitate the material barges, as well as the equipment utilized during the unloading process, play a significant role in maintaining the production rate established at the workface. The advantages of two mooring facilities is addressed in the following subsections along with a discussion concerning the equipment thought to be most feasible for use during unloading operations.

5.3.1. Mooring Facilities

Although the project could probably be completed within schedule with only one 800-foot by 80-foot mooring facility, the advantages of using two facilities justifies the second facility's construction. Two facilities provide redundancy in the event one of the sites is rendered unserviceable due to a sunken barge or damage to the mooring facility itself. The second location also increases the efficiency of unloading materials. Since an 800-foot by 80-foot mooring facility can accommodate as many as six barges (three long by two wide), when two mooring sites are in service, as many as six barges can be unloaded concurrently. This provides a separate berth for each type of material and can greatly enhance the contractor's efforts if work continues on two faces at the same time or if the contractor wishes to accelerate work on only one face. Finally, the second mooring location serves as an additional safety measure in the event that an emergency (i.e., hurricane) dictates that the island be evacuated, including an equipment load-out. Although it is possible to achieve similar results by reducing the second mooring facility by 200 feet, it is probably most useful to the contractor if it is constructed with the same dimensions as the first. This will ensure that a redundancy factor is available should one of the facilities be rendered unserviceable or an emergency evacuation become necessary.

Regardless of the final dimensions on the second facility, it should be noted that the facility is for the contractor's assistance and may only be temporary in nature. Once the project is complete, one of the mooring facilities must remain intact so that the Corps of Engineers will retain the capability of conducting periodic maintenance on the structure. The second facility, however, will no longer be needed and can be eliminated if proven to be less costly than keeping it in place.

The unloading process that occurs at the mooring sites can become extremely congested if sufficient planning has not taken place prior to facility construction. The site must be organized in a manner that provides adequate space for the unloading equipment as well as the equipment to transport the materials to the workface. The majority of the equipment used for unloading will probably be standard cranes, either owned or leased by the contractor. There should be sufficient space for the contractor to employ three cranes at each mooring site (one crane for each barge terminal/berth), as well as one truck (dump or flatbed) per crane.

5.3.2. Material Unloading Equipment

The cranes will not require the same lifting capacities as those used for placement, because the distances in which the cranes must lift the materials is significantly less. When located adjacent to the mooring facility, the maximum lifting radius should not have to exceed 35 to 40 feet (the standard barge width), and thus reduce the crane size and boom length required. The crane attachments used during the unloading process will vary depending on the size and shape of the material being lifted. While the blanket, core and toe stone will probably be unloaded with a standard 2-1/2 to 5 CY clamshell bucket, the armor stone will require a rock grapple, tong, orange peel, or other alternative lifting attachment designed by the contractor. A 50- to 70-ton crane should be sufficient for unloading all materials, with the exception of sheet piles, which will probably require an 80-ton crane or larger, or possibly even two cranes.

Front-end loaders and backhoe excavators can probably help provide assistance during the unloading process. Their lifting radius, however, is somewhat limited, and for the most part they are unable to reach the material across the width of the barge.

5.3.3. Equipment Deployment

The enormous weight of the cranes makes it difficult to deploy them to the island. The cranes may require disassembly prior to transport. If the crane can be dismantled to sizes such that they, along with a tractor-trailer, do not exceed the swing bridge capacity, then they can be transported by wheeled vehicle. If this cannot be achieved, then the cranes should still be dismantled, but, will deploy to the island with the use of barges. A fully assembled crane with a heavy lifting capacity can be secured on an equipment barge so that it can unload the disassembled crane parts as they arrive to the island.

5.4. Surge Storage Considerations

It is essential that sufficient quantities of material are available in a surge storage location prior to beginning construction. This helps to ensure that once construction starts, no idle time will occur due to lack of materials. The distances in which the materials will be traveling and the unlimited number of potential interferences makes "just-in-time" (JIT) delivery a risky approach that could delay the entire project. Although it is possible for 12 barges to be fully loaded and docked at the mooring facility, it is also conceivable that problems encountered along the route or at the quarry site prohibit certain materials from arriving on time. Therefore, it is critical to have a three- to four-day supply of materials stockpiled on the island. The following subsections will address the necessary surge storage requirements, based on the estimated placement rates, as well as the necessary equipment and control measures needed to properly operate the storage area.

5.4.1. Surge Storage Requirements

Based on the estimated placement rates shown in Table 2 (CII 1993), the storage yard(s) should contain approximately 17,000 tons (8,600 CY) of rock (blanket, core and toe stone) and nearly 500 armor units. In addition, during the construction of the sheet pile sections, over 40 piles should be stored. Fortunately, the current plan calls for an 800-foot by 100-foot lay down area adjacent to both mooring facilities. These storage locations should provide adequate space for three to four days of stockpiled materials if they are properly organized. When storing the armor units, they should probably not be stacked on top of one another unless it is absolutely necessary, and then only two blocks high due to damage and handling concerns (CII 1993).

Table 2. Estimated Production Rates

Activity	Production Rate
Excavation	200 CY/Hr
Blanket Stone Placement	150 CY/Hr
Armor Block Placement #1	4 Blocks/Hr
Armor Block Placement #2	6 Blocks/Hr
Armor Block Placement #3	10 Blocks/Hr
Core Stone Placement	100 CY/Hr
Toe Stone Placement	100 CY/Hr
Sheet Pile Placement	1.25 Piles/Hr

Because of the enormous weight of the stockpiled material, a great deal of work must be done to strengthen the existing soil. The storage site will require crushed stone from an outside source and possibly the use of a geotextile fabric. The material used to construct the storage area can probably come from the same source as that for the haul road.

5.4.2. Surge Storage Equipment

Because the majority of the materials used on the project will probably be unloaded from the barges on to trucks so that they can be transported directly to the construction site, the storage yard will probably be drawn upon only when materials fail to arrive on time. Therefore, once the materials have been stockpiled, there should be minimal need for any equipment at the storage yard. A bucket loader can be used to periodically maintain the yard(s) and assist in loading the blanket, core, and toe stone when it is needed. However, in the event that armor units or sheet piles are not available on the docked barges and must be obtained from the storage site, the nearest unoccupied crane with the appropriate lifting device must be deployed from the mooring facility to load them on to the transport vehicle. Although this might require some additional time, it is more cost effective than keeping a crane at the storage location at all times.

5.4.3. Surge Storage Controls

The designated surge storage yards adjacent to the mooring facilities are to assist the contractor in maintaining a sufficient quantity of supplies on the island should material transport be delayed. Additional staging areas can also be established along the 300 foot right-of-way if the contractor deems it necessary. This would provide the contractor more flexibility in choosing where the materials would be most accessible and safeguarded from the environment. The contractors at the CII constructability symposium also suggested that in order to improve control of the delivery process, it may be worthwhile to establish a river control point somewhere along the GIWW (CII 1993). This would enable barges to be staged and called to the island when they are needed. It also would eliminate congestion if the mooring facilities are already occupied and several barges arrive with materials.

5.5. On-Land Transport

Once materials have arrived at the mooring facilities on the island, it is probable that they will be _sported to the construction site by wheeled vehicles. Off-highway, rear-dump haulers ranging from 20- to 40-ton carrying capacities (12-1/2 to

30 heaped cubic yards) should be of sufficient size to carry the blanket, core, and toe stone. The equipment at the mooring facility should be able to load these trucks to capacity in 10 to 15 minutes. The trucks are capable of reaching speeds in excess of 40 miles per hour (MPH), although they will probably be limited to less than 35 MPH. The width of the larger dump trucks is approximately 14 to 15 feet, which can make passing one another on the haul road difficult. The empty operating weight of the trucks exceed 60,000 pounds, which eliminates the use of the 26-ton swing bridge (CAT 1991). Therefore, along with the cranes, the larger dump trucks will require transport to the island by barge. The smaller 20- and 25-ton haulers, however, should be able to gain access to the island over the swing bridge when they are empty.

Unlike the quarried stone, the armor units and sheet piles will need to be transported from the mooring facility to the workface in a more organized, careful fashion. The average tractor and trailer combination can handle a 40-ton load, however, depending on the number of axles and the configuration of the trailer, larger loads can be transported. Together the combination usually ranges from 40 to 50 feet long and weighs approximately 15 to 18 tons (Nichols 1976). Typically, the truck-tractor and semitrailer are somewhat restricted during off-highway operations, but should have no difficulties transporting material along a well constructed haul road. The requirements for the haul road are addressed in the following subsections along with a brief discussion of other alternative means of transportation.

5.5.1. Haul Road

The haul road is a critical element in the construction process. Its strength and durability affect the load size and transport speeds that the material haulers are permitted to achieve. In order to construct the haul road, the contractors at the CII symposium felt that, although river run stone would probably work effectively, crushed limestone appears to be the best choice (CII 1993). It has been used on several similar roads in Louisiana and has proven adequate. To help improve the road's stability, a geotextile fabric should be incorporated into the design.

The road should be designed wide enough to handle material transporters passing one another as well as allow truck-mounted cranes the ability to employ their outriggers so that periodic maintenance operations can take place once the structure is completed. Other than the truck-mounted cranes that will perform periodic maintenance repairs on the structure in the future (possibly every five to ten years), the only equipment that will use the haul road will be vehicles transporting materials from the mooring facility to the work site. The material placing equipment will not have to use the haul road if a crane lane is constructed.

In order to reduce the transport cycle time and provide additional safety precautions, turn-around points should be constructed at random locations along the haul road. The turning radius for most dump trucks and tractor trailer combinations usually varies between 23 and 33 feet (Nichols 1976). The contractor should have the opportunity to determine the locations for turn-around points. However, in order to be fully effective, some of the points may have to exceed the proposed construction rights-of-way. If this, in fact, is the case, the contractor must notify the Corps as soon as possible so that additional land may be leased temporarily. If the additional land can not be obtained, the proposed turn-around point will have to be relocated or eliminated completely.

It was suggested at the contractor's symposium that the splash apron be extended enough to construct the service road right on top of it by choking the armor blocks and core stone with additional crushed limestone. This might be a good alternative for a service road once the project is complete. Because of the slope of the excavation, however, construction will start from the toe of the structure and move upward. This makes the splash apron nearly the last element to be completed, and is thus eliminated as a usable transport road for haul vehicles.

5.5.2. Other Means of Transport

During the CII constructability symposium, rail was mentioned as an alternative form of transportation on the island. However, this option was determined to be infeasible because the existing soil conditions would make it extremely difficult and costly to construct a railroad on the island.

In addition, a "wet method" of construction was discussed, which entailed excavating a channel trench along the trace of the structure so that construction could take place with the use of floating equipment. The Corps of Engineers rejected this method because they feared that an excavated channel would increase the possibility of an ocean breach. This method would also require a great deal of additional real estate be acquired.

The final mode of transport to be considered to haul materials from the mooring facility to the workface was a belt conveyor system. Unfortunately, although a conveyor system is capable of delivering materials in a rapid manner, the actual dimensions of the material being delivered is severely limiting. For the Sargent Beach Project, blanket stone and clay backfill are probably the only materials that would benefit from a conveyor system. The other materials (core and toe stone, armor units, etc.) are too large for such a system and must rely on trucks or heavy equipment for their transport. Therefore, it does not appear to be cost effective to establish and maintain this additional transportation method.

5.6. Placement Site Handling Equipment

The equipment requirements for each of the primary construction tasks are addressed in the following subsections. The tasks are organized in a sequence similar to that which will occur during the construction process.

5.6.1. Excavation

Due to the large volume of soil to be excavated, it is crucial for this phase of the construction process to remain on schedule. The rate at which the in-situ material is removed is a critical element that affects the placement rates of all the other materials. A crawler-mounted dragline is probably the most suitable piece of equipment for this particular phase of the operation. The nominal bucket capacities range in size from one-half to 20 cubic yards (CY). However, depending on the cycle time, a standard four to six CY dragline bucket should be sufficient. If an operator can maintain a 60 to 90 second cycle time with a five CY bucket, then it is possible to excavate approximately 200 to 300 CYs per hour. This is the estimated production rate that must occur in order to maintain the proposed three-year schedule.

In order to maximize the casting and dumping radius of the dragline, a larger boom (80 - 100 feet) should be utilized. This, however, requires the use of a larger crane than those used at the mooring facility. A 100- to 110-ton crane should be capable of handling a five CY bucket along with a boom of sufficient length to properly excavate the material (FMC 1981).

Because the casting radius (the distance the bucket is thrown when excavating) normally exceeds the dumping radius (the distance the bucket is capable of dumping excavated material), a bulldozer should be employed to help move the excavated material far enough away from the line of construction so that the spoil pile will not create undue surcharge loading and cause the excavated bank to collapse. This will help reduce the excavation cycle time.

A detailed investigation should take place to determine how far from the edge of the excavation face the spoil pile should be located so as to avoid slope failure. The Corps can either: 1) determine this and specify it in the contract documents, or 2) leave it up to the construction contractor to determine, which was the contractor's preference in the CII symposium (CII 1993).

5.6.2. Blanket Stone and Toe Stone

The blanket and toe stone, as well as the six-ton armor units, also require large cranes for their placement. The lifting radius for the toe stone, some of which weigh up to 4,000 pounds, range from 100 to over 140 feet, depending on the structure's various cross-sectional designs. Therefore, a crane capacity in excess of 100 tons will most likely be needed (FMC 1981). The blanket stone, although not nearly as heavy, also requires a crane and boom that can place materials in excess of 120 feet. A 2-1/2 to 5 CY clamshell attachment should have no significant problem placing 150 cubic yards of blanket stone per hour. The larger toe stone, however, will probably only achieve a placement rate of 100 CY per hour with the same equipment. If available, rock slings and grapples are alternative attachments that could also be used to effectively place the toe stone. If these methods are used, however, it is necessary to closely monitor the placement operation so that material segregation does not exceed the allowable limits.

5.6.3. Armor Units

The armor units are perhaps most important for revetment stability. The land-based cranes used to place the blocks should have an attachment that can carefully place and release the units under water once they are set (perhaps one of the alternatives mentioned in Section 5.1.2.). The units will be handled individually and will be retrieved from the back of a flatbed semitrailer so that they will not have to be double handled. The lifting radius required for the cranes placing the blocks varies from 30 to 120 feet. Since typically there will be more than one crane placing armor units on a workface, the crane(s) placing the blocks with a smaller radius (less than 60 feet) should be 70 to 90 tons, while those placing the blocks over 60 feet out should meet or exceed the 100- to 110-ton crane capacity (FMC 1981).

5.6.4. Core Stone

The core stone portion of the structure will probably be the least difficult to construct. It is entirely above water and is located relatively close to the haul road (20 to 30 feet). Front-end bucket loaders and backhoe excavators can easily place the core stone without the use of cranes. They should obtain the material from a stockpile established by the haul units which are transporting the rock. A 2-1/2 to 5 CY bucket should have no problem in exceeding the 100 CY per hour production rate mentioned in Table 2.

5.6.5. Sheet Pile

In addition to the normal equipment needed to place armor blocks and blanket, core, and toe stone, the sheet pile sections require several additional items. A piling template should provide sufficient guidance so that the pile will maintain its correct alignment through the entire driving operation.

A wide variety of pile driving hammers can effectively install concrete sheet piles. Some of the possibilities include (ASCE 1984):

a. Drop hammer. This is the simplest type of hammer available, however, it probably has the slowest striking speed and can easily cause damage to the pile if an excessively high drop is adopted when driving becomes difficult.

b. Single-action hammer. This hammer generally ranges in mass from 2 to 15 tons and normally has a maximum striking rate of 55 to 60 blows per minute. It is capable of driving all types of piles, but is most suitable when driving into stiff or hard clays where a heavy blow with a small drop is most efficient and least damaging.

c. Double-action hammer. These hammers have a relatively short stroke, a lightweight ram, and operate at a high speed (approximately 100 to 200 blows per minute) compared to that of single-action hammers. This hammer is most effective in granular soils.

d. Diesel hammers. These hammers are suitable for all types of soil, with the exception of extremely soft clays. Diesel hammers are most effective when driving into stiff to hard clays.

Additional alternatives (vibratory drivers, differential hammers, etc.) have also proven effective in special situations, however, those listed above are the primary methods. The pile driving method should probably be left up to the contractor.

5.6.6. Clay Backfill

The compacted clay backfill section still contains a great deal of construction method uncertainties. How the section will be dewatered prior to compaction is perhaps the greatest question. The Corps believes sump pumps will provide adequate dewatering capabilities and thus well points should not be required (CII 1993). The contractors at the symposium, however, were somewhat skeptical about the dewatering capabilities and felt that a pre-bid demonstration may help answer some of the uncertainties bidders might have. If dewatering is proven effective, then several equipment alternatives can provide adequate compaction. A sheepsfoot or "Bomag" roller is probably the most effective piece of equipment when attempting to compact soil that is high in silt and clay content (CAT 1991). As shown in Figure 4, Chapter 2, the remainder of the clay backfill section is similar to the standard cross-sectional revetment and the equipment used should be no different.

5.7. Summary

Overall, the contractors at the CII constructability symposium felt that there should be no significant problems regarding the availability of equipment and that the majority of the equipment used on the project is standard in design.

The actual construction placement sequence will be addressed in more detail in Chapter 6.

6. WORK SITE OPERATIONS

6.1. Construction Sequence

Normally the Corps leaves the decision on the sequence of construction to the contractor. However, because of the increased likelihood that an ocean breach can occur at the most vulnerable areas (McCabe Cut and Choctaw Lake), the Corps should dictate that these sections be constructed first. Failure to clearly state in the contract documents that these areas be constructed first, relieves the contractor of any responsibility for protecting the most vulnerable areas. The areas most vulnerable to an overwash are located a substantial distance from one another. However, both are relatively close to the proposed mooring facilities. This therefore provides an ideal opportunity for the contractor to operate at two work faces simultaneously.

The following four subsections provide a detailed explanation of the construction work site, to include workface layout and proposed sequence of construction.

6.1.1. Workfaces

Although the consensus at the CII symposium was to operate from only one work face, the CII-generated, three-year schedule and simulation dictates that two work faces need to be operated concurrently (CII 1993). Operating from two work faces would significantly reduce the time required to construct the erosion control structure. By operating from two work faces concurrently, the estimated construction duration should be reduced from 762 days to 403 days based on the deterministic model (CII 1993). However, if a second work face is not utilized, then it would probably be necessary for the contractor to incorporate a second and third shift or an extensive amount of overtime to successfully complete the project on schedule. The contractor also has the option of increasing the amount of equipment used on one work face so that the production rate is similar to that of two work faces. This, however, may cause a great deal of traffic congestion and equipment interference due to the limited accessibility provided by the haul road.

6.1.2. Workface Layout

A proposed layout for each work face is presented in Figures 6 and 7 (the typical 1V:2.5H concrete block revetment section and the concrete sheet pile wall section, respectively). The amount of equipment required on each work face is already quite extensive and because work can only be performed from one side of the structure, doubling the equipment can easily result in interference. Four or five cranes are used for stone, armor unit, and pile placement, while an additional one or two cranes with draglines are used for excavation and backfill. Severa: oulldozers and backhoes might also be employed to assist in the construction process.

6.1.3. Sequence of Construction

The sequences of construction on each work face differ from one another depending on the cross-sectional design. The construction is an ongoing process, moving continuously in increments until the section is complete. The largest section of the structure is the typical 1V:2.5H concrete block revetment. It will be constructed starting from the toe of the structure and moving upward, with the exception of the placement of the toe stone, which will occur last. The basic construction sequence for this section is displayed in the following list and shown in Figure 6:

a. Excavate in-situ material.
b. Place geotextile fabric.
c. Place blanket stone.
d. Place armor units (three cranes placing armor units).
e. Place core stone.
f. Place toe stone.
g. Backfill and grade.

The sequence for the typical 1V:5H concrete block revetment section is similar, with the exception of dewatering the excavated portion and placing a compacted clay backfill prior to installing the geotextile fabric.

The sequence for the concrete sheet pile wall section requires that the wall be subjected to the minimum amount of surcharge at any one time. The construction sequence for the sheet pile wall section is listed below and shown in Figure 7:

a. Set and drive sheet piles.
b. Place pile cap (precast or cast-in-place).
c. Excavate GIWW side of wall.
d. Excavate Gulf side of wall.
e. Place blanket stone on Gulf side.
f. Place armor units on Gulf side (two cranes placing armor units).
g. Place toe stone on Gulf side.
h. Backfill and grade Gulf side.
i. Place blanket stone on GIWW side.
j. Place core stone on GIWW side.

6.1.4. Crane Access

As mentioned in Section 5.5.1., the haul road should be designed to accommodate trucks passing one another. However, with the large amount of equipment needed on each work face, an additional lane or area must be designated adjacent to the road so that cranes can position themselves off to the side of the primary road yet have access to both material being delivered and to the work face

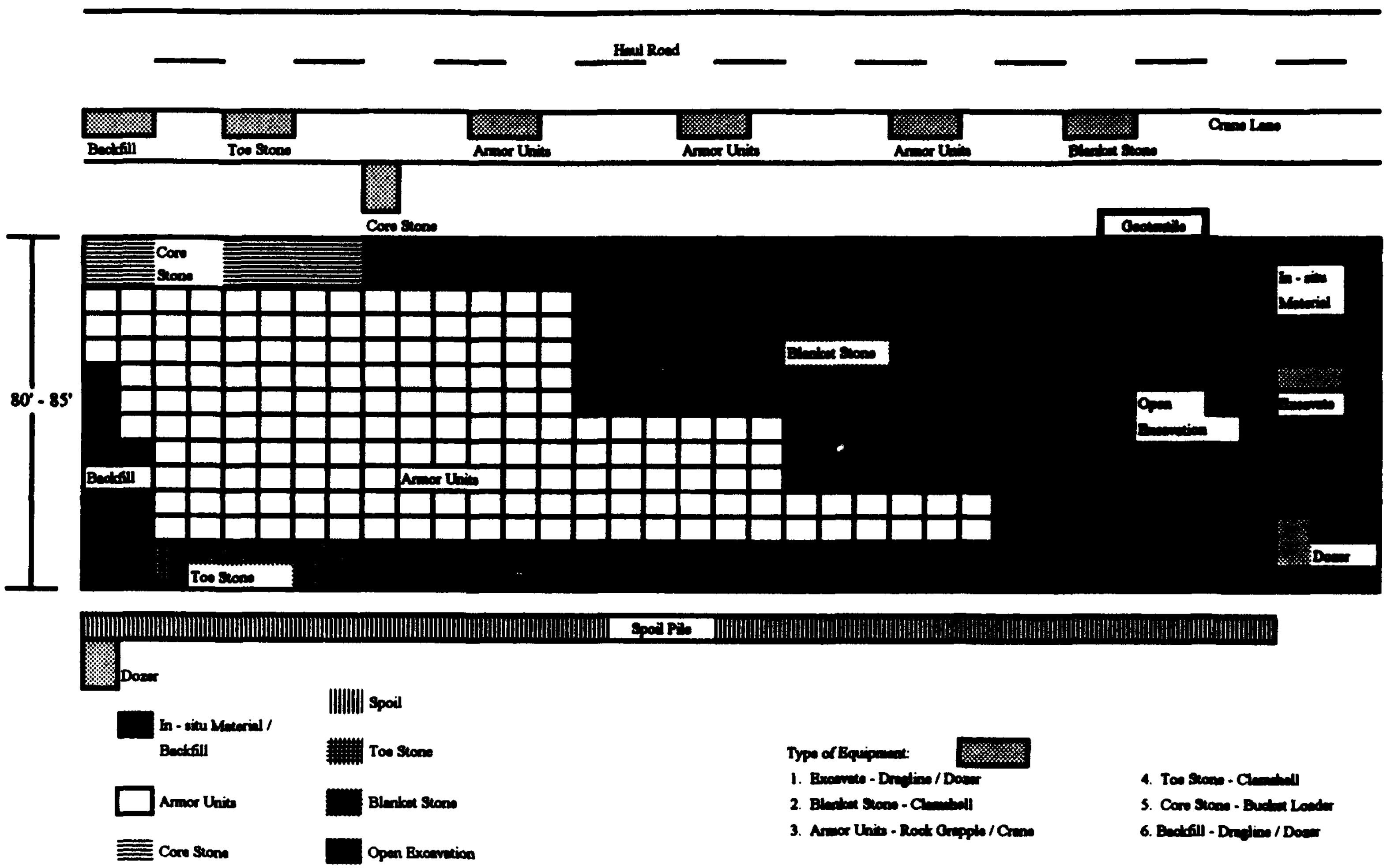


Figure 6. Workface Layout - Typical 1V:2.5H Concrete Block Revetment

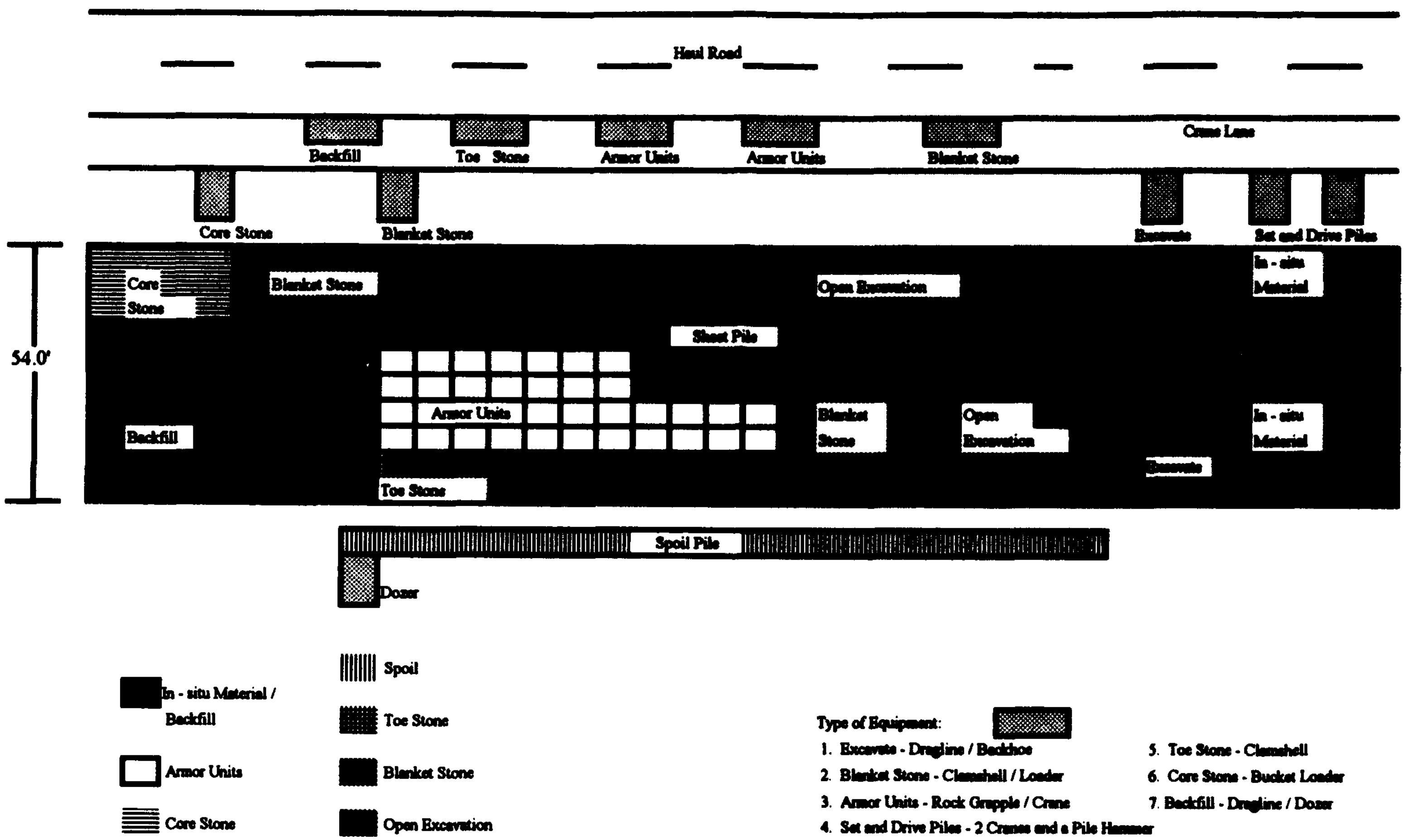


Figure 7. Workface Layout - Sheet Pile Wall

(Figures 6 and 7). Provision of a stable, off-road base for cranes can rely on any of several contractor selected options such as: crane matting, geotextiles in conjunction with compacted fill material, etc. Cranes must not work from the primary haul road during construction as they will interfere seriously with traffic and will increase the crane lifting radius.

6.2. Excavation and Shaping

The enormous excavation requirements for this project (over one million cubic yards), constitute the most critical element in the construction process. The rate of excavation will determine the production rate for every other aspect of the project. Therefore, it is essential that proper equipment be employed for excavation. The rate of excavation is determined to be 200 CY per hour in order to maintain an adequate schedule (CII 1993). This excavation rate requires that a five CY dragline bucket maintain a cycle time of 90 seconds for eight hours a day. The excavation rate can easily be increased by reducing the cycle time or by increasing the bucket size. The use of two draglines using a staggered approach is not recommended, however, because this may: 1) cause unnecessary interference with one another when dumping spoil, since all spoil is placed on the Gulf side of the structure, and 2) exceed the surcharge limits because of extremely weak soil conditions.

If the five CY dragline cannot maintain an excavation rate of 200 CY per hour, then a good argument can be made for operating two work faces simultaneously. The crane(s) performing the excavation function should be located along the structure trace as opposed to on the crane lane.

A brief explanation of the excavation process and the location of the spoil pile is addressed in the following two subsections.

6.2.1. Open Excavation

During excavation, the face should be left open for as short a time as possible. The open face is extremely vulnerable to storms and could result in an overwash or breakthrough. The Corps should place reasonable limitations in the contract documents as to the amount of open excavation permitted. The contractors at the CII symposium felt 200 to 300 feet of open excavation should be sufficient (CII 1993). The distance between the head of the excavation and placement of the armor units should be minimized to that required by crane safety considerations so that the risks of storm damage and slope failure are reduced. The fact that the excavated portion of the structure does not have to be dewatered, with the exception of the typical 1V:5H concrete block revetment section, will help maintain slope stability.

6.2.2. Spoil Pile

The location of the spoil pile can also affect slope stability and must be calculated to prevent undue surcharge. The result of the calculated location may impact the equipment selected for the process in that a dragline rigged to operate at an acceptable cycle rate may not be able to dump the spoil far enough off to the side. If this is the case, a larger crane and boom may be necessary or a bulldozer may be needed to push the spoil a sufficient distance away from the open cut. This will insure against slope failure.

6.3. Geotech Fabric Placement

Once excavation is complete, a standard geotextile fabric can be installed. The contractors at the symposium felt that placement, even underwater, is relatively simple and requires no special equipment. The geotextile comes on a large spool and can be rolled out manually in a similar fashion to carpet. The process is relatively inexpensive, requires little time for installation, and is so advantageous that contractors suggested the fabric underlie the entire cross section and not just the upper half. They believe that the textile should be utilized for all of the cross-sectional designs (CII 1993).

Geotextile fabrics are generally procured in standard widths of six to 18 feet. Prior to placement, however, several sections are preassembled so that the number of overlaps is minimal. The preassembled sections are usually sewn together or bonded by cementing or heat. However, once the preassembled sections are placed underwater, it becomes much more costly to connect them with sewing or bonding. Therefore, the contractors at the CII symposium suggested that the preassembled sheets be overlapped instead of mechanically or chemically connected. In order to provide sufficient protection, it is recommended that the preassembled sheets be overlapped by three feet when installed underwater (DA 1986). Temporary pinning or connected weights are capable of holding the fabric in place until the blanket layer can be placed.

6.4. Pile Placement

The sheet pile construction sequence outlined in Section 6.1.3. helps to eliminate unacceptable pile loading during the placement process. Because the sheet piles are driven first, the excavation must be executed carefully to avoid damaging the piles. The pile cap is installed prior to excavation so that point loads can be distributed over a larger area. It will probably be necessary to cut or splice piles before installing the pile cap. If driving piles with an impact hammer becomes difficult and causes pile damage, predrilling or jetting may be required. A pre-bid test pile demonstration should help in deciding acceptability of this option. If jetting is used, contractors at the symposium recommend that tiebacks be incorporated into the sheet pile wall design (CII 1993). Careful control is required to assure sufficient penetration to intercept high potential breakthrough sections. The following two subsections discuss the site preparation and pre-bid demonstration associated with the pile driving operation.

6.4.1. Site Preparation

Several areas along the trace requiring sheet pile wall are low and covered with water. Prior to setting or driving the piles, considerable site preparation may be needed. The low sections may require compacted fill material to facilitate equipment access and material delivery.

6.4.2. Pre-bid Demonstration

Equipment required for the pile driving operation can be determined during the pre-bid demonstration. A pile template will undoubtedly be used to keep the structure in proper alignment. Considering pile size and weight, one crane will probably be used to set piles while a second crane drives the pile to the desired depth. The placement rate for the entire sheet pile cross section (to include armor units, blanket stone, etc.) is 10 sheet piles per day or approximately 20 linear feet per day.

6.5. Core Stone/Toe Stone/Blanket Stone Placement

During the placement of core, toe, and blanket stone, trucks should be utilized to the maximum extent possible. The stone should be delivered to a designated location and then stockpiled so additional material can be unloaded. The equipment placing the stone will retrieve and place the stone in proper position. Cranes with a clamshell attachment will probably be used to place the toe stone and blanket stone, while the core stone will most likely be positioned with the use of a large front-end loader. When determining the most feasible method for placement, stone weight, lifting radius, and dump height are all taken into account. The following subsections will address these factors in attempting to determine which pieces of equipment are most suitable for stone placement.

6.5.1. Equipment Requirements for Core Stone/Toe Stone/Blanket Stone Placement

The cranes needed to place the blanket and toe stone will probably have similar load-carrying capacities. The crane placing the toe stone, however, will require the longest boom because of the large swing radius. Although the toe stone only requires a 50-70 foot swing radius for the concrete sheet pile wall section, a 130-150 foot swing radius is needed to place the stone on the typical 1V:5H concrete block revetment section. The swing radius for the crane placing the blanket stone varies between 20-130 feet.

The equipment placement lane should be stabilized considering both the crane load and the weight of stockpiled stone. The equipment lane should be placed to minimize the crane's swing radius.

Core stone will all be placed above the water surface, and the final location should be readily accessible to a wheeled- or crawler-mounted front-end loader or backhoe excavator.

6.5.2. Placement of Core Stone/Toe Stone/Blanket Stone

When placing the toe stone and blanket stone below the water surface, it is important to minimize the dump height so that segregation does not seriously affect the finished structure. Toe stone will be the last element put into position. In order to minimize vertical slippage and control toe erosion it becomes essential to closely monitor the placement to prevent segregation. The distances between the placement for each type of material should also be minimized to reduce the possibility of damage caused by severe weather. The distances between each material source should be determined based on the material's placement rate as well as the equipment's safe swing radius.

6.6. Armor Stone Placement

The armor unit layer is the most important element in the erosion control structure because it provides the majority of the structure's stability. It should be placed as soon as possible following the placement of blanket stone in order to provide additional support and assist in preventing any damage that might occur to the sublayers due to severe weather. Because of the extreme importance of the armor unit layer it is imperative that the proper equipment and handling techniques be employed. The following subsections will address the equipment requirements needed during armor stone placement as well as placement tolerance criteria.

6.6.1. Equipment Requirements for Armor Stone Placement

Armor blocks will be placed directly from the back of a flatbed trailer into their specified position. Attempting to handle the blocks in multiples would significantly increase the likelihood of damage during placement; therefore, they will be placed one at a time. During the construction of the typical 1V:2.5H concrete block revetment section, three cranes should be employed on each work face for the placement of armor units (Figure 6). Since the structure will be built from the toe upward, the lead crane should be responsible for placing the first two to three armor units furthest away from the splash apron and in the deepest water. The second crane, without interfering, should be responsible for placing the next three to four blocks closer to the apron. The third crane should place the final four to five blocks in the structure's cross section. The third crane is capable of placing more blocks because the lifting radius is significantly less and the placement occurs above water level. The number of cranes actually utilized on each section will vary based on the percent utilization of each piece of equipment as well as the safe swing radius for the crane's boom. The construction will be a continuous process that takes place in an echelon format (i.e., as soon as the crane placing the blanket stone is sufficient distance from the crane placing the initial armor blocks, the armor block crane will begin operation). The cranes will maintain approximately the same distance between one another so that they continuously move toward the section's completion point. As each crane successfully completes one section, it will be deployed to the next section.

6.6.2. Tolerance Specification for Armor Stone Placement

Because of the critical importance that armor units be laid in a tight uniform fashion, it is imperative that placement tolerances be clearly specified in the contract. Specification terminology is often ambiguous and leads to follow-on problems. Phrases such as, "minimum practicable voids," "reasonably well graded," and "stone shall be placed as closely together as practicable," often confuse the contractor (ASCE 1992). Tolerances specified in the contract should not be unreasonable or the placement costs will increase significantly. The contractors at the constructability symposium felt that a 12-inch tolerance between blocks placed underwater was acceptable (CII 1993). However, those blocks above the water level can be placed with far more accuracy and may only require a six-inch gap tolerance. Testing at the Waterways Experiment Station at Vicksburg, Mississippi, showed that vertical separation under wave action occurs due to slippage and makes the tolerance level critical. The horizontal gaps between the blocks did not prove to be a significant problem when subjected to wave action (CII 1993).

6.6.3. Special Armor Units

Specially sized armor units may be required to prevent unnecessary gaps in transition and closure sections where two work faces connect. Under these circumstances, special armor blocks can be manufactured at the precast yard without significant cost increase. Because of the relatively simple design, the precast yard can adjust the forms to meet the needed size requirements. Additional blocks fabricated for follow-on maintenance operations should not be required. Once again, the block's simplicity enables the design to be duplicated on short notice with relatively few problems. Therefore, any blocks needed for follow-on maintenance should be procurable on an as-needed basis.

6.7. Backfill and Final Grading

The final function in the construction process is backfilling and grading. The backfilling will take place with a dragline bucket on the GIWW side and a large bulldozer operating from the Gulf side. The dragline bucket is capable of handling a large volume of backfill and is better suited for dumping material into a large open trench filled with water. The dozer is on hand to help make the material more accessible for the dragline in the event the boom cannot fully reach the spoil pile on the Gulf side. The dozer is also capable of assisting in the final grading process.

The majority of the material excavated should go back. However, because of the additional materials placed in the trench in order to build the erosion control structure, all of the excavated earth will no longer fit into the original location. Therefore, excess material should be uniformly distributed to provide an additional erosion buffer. The final grading can best be accomplished by a large motor grader.

Once the material has been replaced and final grading is complete, restoring the vegetation will help control erosion. The amount of site restoration, including vegetation replacement, should be specified by the Corps in the contract. In addition, the contract should detail the requirements for excavating and disposing of contaminated soil which may be encountered during the construction process.

7. CONCLUSIONS AND RECOMMENDATIONS

Conclusions regarding the Sargent Beach constructability issues have been assembled below for easy reference. Paragraph numbers relate to sections of earlier chapters that contain discussion and support for the conclusions drawn.

Recommendations determined from the contractor's symposium and from personal interviews and literature research analyses are also presented for consideration in preparation of contract documents. Discussion of issues leading to these recommendations is incorporated in the preceding chapters. Where recommendations depend in part upon assumptions, every effort has been made to acknowledge these assumptions so that the risk inherent in a decision can be evaluated. It is believed that adoption of these recommendations will result in improved contractor performance, lower bid prices, and lower final cost to the Government.

4.2. Material Selection Factors

Conclusions:

1. Material costs are competitive; therefore, transportation costs are the influencing factor in material source selection.

4.3. Material Options

Conclusions:

1. Typically, hard rock costs 15-20 percent more than the softer carbonate stone. It is, therefore, unlikely that granite will be able to compete for use as blanket, core, or toe stone.
2. Sulfate-resistant cement, special blended cement, or appropriate admixtures in the concrete mix will be required for precast unit durability in sea water.

3. Crushed limestone should be sufficient aggregate for the concrete armor blocks.

Recommendations:

1. Precast concrete armor blocks should have a minimum strength of 3,500 psi and should contain sulfate resistant cement.
2. The armor unit concrete specifications should allow use of commercially available cement and aggregate.

4.4. Sheet Pile Wall

Conclusions:

1. Contractors have considerable concern about the sheet pile wall design. They fear that the cantilevered wall might collapse without the use of tiebacks.
2. The use of concrete sheet piling could increase the overall project cost by as much as two million dollars over the cost of an equivalent length of standard revetment.

Recommendations:

1. The Corps should consider complete elimination of the sheet pile wall and substitution of a more easily constructed revetment section.
2. If sheet piling must be retained, concrete units should be replaced with steel sheet piling fabricated of corrosion-resistant steel with a protective coating and cathodic protection.
3. The Corps should use procedural specifications if the concrete sheet pile wall remains in the design.
4. A test pile demonstration should be undertaken to help eliminate some of the uncertainties during bid preparation.
5. A precast pile cap should be used instead of a cast-in-place cap.

4.5. Geotextile

Conclusions:

1. Geotextile fabric is available in various compositions and can usually be purchased as a standard off-the-shelf item.

Recommendations:

1. A geotextile fabric should be considered for use throughout the entire cross-section of the revetment structure instead of only the upper-half.

4.6. Locations Studied and Results, By Material Type

Conclusions:

1. Blanket stone, core stone, and toe stone needed for this project can be obtained from a single supplier.

2. There are numerous quarries within the State of Texas which can fulfill project needs. In addition, stone quarries along the Mississippi, Ohio, and Arkansas Rivers are capable of providing adequate stone.

3. Very few quarries within Texas have access to a navigable waterway. Therefore, truck or rail must be used to haul the material to the nearest port.

4. Quarries located along the Mississippi, Ohio, and Arkansas Rivers have a significant advantage in that they have direct access to a navigable waterway.

5. The quarries should be able to produce a minimum of 5,000 tons of stone per week.

6. The average price of riprap at the larger quarries is expected to be $7-$8 per ton, excluding transportation and handling costs.

7. The rectangular design for armor block will increase the cost of producing the right sized granite unit. Granite probably will not be able to compete financially against the concrete option.

8. The majority of the contractors attending the CII Constructability Symposium favored precast concrete for use as armor units.

9. Contractors agreed that the only economical means of transporting the precast armor units is by barge.

10. Although several precast yards operate in Houston and Freeport, Texas, there are very few which have direct access to a navigable waterway.

11. The majority of the large contractors felt they would establish their own armor unit casting yard.

12. Fortunately, several of the larger contractors already own property in the Houston or Freeport area adjacent to a waterway. Other contractors can obtain access.

13. There are large deposits of sand and gravel adequate for concrete along the Colorado River in Texas. Commercial aggregate is readily available in Victoria, Eagle Lake, and Columbus, Texas.

14. Because of reinforcement and pretensioning requirements for concrete sheet piles, contractors will probably purchase piling from an outside supplier as opposed to manufacturing their own.

Recommendations:

1. Specification compliance should be verified by visual inspection at the quarry site.

2. The quality requirements for stone should be addressed specifically in the contract documents.

3. Consideration should be given to combining size and weight specifications for core stone and toe stone to permit elimination of one category.

4. The precast yard should be designed to produce up to 250 blocks per day when two work faces are operating concurrently.

5. Block shop drawings should incorporate provisions to facilitate handling and placement.

6. The Corps should use performance specifications for armor blocks so that contractors have maximum production and handling flexibility.

7. The concrete sheet pile supplier should be capable of producing at least 10 sheet piles per day, five days per week with provision for expansion if required to meet placement demand.

5.1. Production Site Handling

Conclusions:

1. Quarries located along the Mississippi, Ohio, and Arkansas Rivers will ship stone directly by barge with a minimum of rehandling. Quarries located throughout Texas will load stone on trucks or rail cars, initially.

2. A typical 100-ton gondola rail car can be loaded with a standard five-cubic yard bucket in less than ten minutes.

3. A crane with a rock grapple, orange peel, or specially designed attachment can probably place 12 to 15 granite blocks on a flatbed rail car within 10-12 minutes.

4. Several established precast yards are equipped with an overhead crane system that can rapidly transport and load concrete armor units and sheet piles.

5. A contractor's ingenuity in devising an efficient method of handling armor blocks has the potential to pay large dividends.

6. Since reinforced concrete piles generally have a relatively low resistance to bending, stresses caused during lifting may dictate the amount of longitudinal reinforcing steel needed.

Recommendations:

1. Concrete sheet piles should be designed and marked to insure safe pickup and handling.

5.2. Production Site to Job Site Transportation

Conclusions:

1. The only feasible method of getting heavy materials to the island is by barge transport. Use of the swing bridge must be limited to small vehicles carrying personnel and light equipment.

2. Blanket, core, and toe stone that originates from quarries along the Mississippi, Ohio, and Arkansas Rivers can be transported directly by barge from the quarry site to the island.

3. Most barges used to haul stone have a 1,500 ton capacity, require a 9-foot draft, and have an average dimension of 35 feet by 195 feet. The average rental rate ranges from $150 to $275 per day.

4. The total distance traveled from Cape Girardeau, Missouri, to Sargent Beach, Texas, is approximately 1,350 miles. It takes from 12 to 17 days to transport cargo over this distance. This results in an estimated transportation cost of $2 per ton, when only using barge rental cost data. The additional tug expenses can be negotiated, but will still significantly increase the overall transportation cost.

5. Months with the least amount of barge traffic (and delays) are March, April, and May, whereas the months most traveled are August, September, and October.

6. Several of the larger quarries in Texas have a railroad spur that merges with a statewide rail network. The distance from quarries located along the Balcones fault zone to Sargent Beach is nearly 200 miles and should take no longer then 24 hours. The estimated transportation cost ranges from $6 to $8 per ton (minus double handling during transfer and barge and tow expenses necessary to transport the material to the island).

7. The estimated travel time from Houston to Sargent Beach for a six-barge raft is 20 to 24 hours. Therefore, the average cost for transporting concrete armor units from Houston, or any other location with approximately the same travel distance, is $0.17 per ton or about $1 per block. (Once again this estimate only uses the cost data from barge rental expenses and does not include towing costs.)

8. The highway weight limitation imposed by the Texas Department of Transportation is 40 tons and limits the number of units carried per truck.

Recommendations:

1. Barges should be used to transport heavy materials to the island, and that any use of the swing bridge should be limited to small vehicles carrying personnel and light equipment.

5.3. Job Site Off Loading

Conclusions:

1. Most of the equipment used for unloading will be standard cranes.
2. While blanket, core and toe stone will probably be unloaded with a standard 2 1/2 to 5 CY clamshell bucket, armor stone will require a rock grapple, tongs, orange peel, or specially designed lifting attachment. A 50- to 70-ton crane should be sufficient for unloading all materials, with the exception of sheet piles, which will probably require an 80-ton crane or larger.

Recommendations:

1. Two mooring facilities of equal dimensions should be constructed prior to award of the main project contract.
2. The mooring facilities should be designed to provide sufficient space for the contractor to employ three cranes at each mooring site (one crane for each barge terminal/berth), as well as one truck (dump or flatbed) spotting area per crane.

5.4. Surge Storage Requirements

Conclusions:

1. The 800-foot by 100-foot lay down areas adjacent to both mooring facilities should provide adequate space for a three to four day emergency supply of stockpiled materials.
2. Because of the enormous weight of the stockpiled material, preparatory work must be done to the storage yards to strengthen existing soil.
3. The storage yard will probably be drawn upon only when materials fail to arrive on time. Therefore, once the materials have been stockpiled, there should be minimal need for any equipment at the storage yard.
4. Contractors at the CII Symposium suggested establishment of a river traffic control point somewhere along the GIWW to improve control of the delivery process.

Recommendations:

1. Sufficient quantities of material should be available in a surge storage location prior to beginning construction. A three- to four-day supply of materials stockpiled on the island should provide adequate quantities in the event of material delivery delay. The surge storage yard(s) should contain approximately 17,000 tons (8,600 CY) of rock (blanket, core, and toe stone) and about 500 armor units. In addition, during the construction of the sheet pile sections, approximately 40 piles should be stored.

2. Armor units should probably not be stacked on top of one another unless it is absolutely necessary and then only two blocks high.

3. Additional staging areas along the established right-of-way should be permitted if the contractor deems them necessary.

5.5. On-Land Transport

Conclusions:

1. Materials will be transported to the construction site by wheeled vehicles. Off-highway, rear-dump haulers ranging from 20 to 40 ton carrying capacities (12-1/2 to 30 heaped cubic yards) should be of sufficient size to carry the blanket, core, and toe stone. Equipment at the mooring facility should be able to load these trucks to capacity in 10 to 15 minutes.
2. Crushed limestone appears to be the best choice for constructing the haul road.
3. The splash apron is nearly the last element to be completed, and is thus eliminated as a usable transport road for haul vehicles.
4. The rail option is considered infeasible because existing soil conditions would make it difficult and costly to construct a railroad on the island.
5. The "wet method" of construction is not considered a feasible alternative because of the increased likelihood of an ocean breach.
6. Blanket stone and clay backfill are probably the only materials that would benefit from a conveyor system. Other materials are too large. This problem makes conveyor systems infeasible.

Recommendations:

1. Geotextile fabric should be considered for incorporation into the haul road design to help provide stability.
2. The contractor should determine haul road width and location of passing turnouts as needed to support his job strategy.

5.6. Placement Site Handling Equipment

Conclusions:

1. A 100- to 110-ton crane should be capable of handling a five CY dragline bucket along with a boom of sufficient length to properly excavate the material.
2. The required lifting radius for toe stone ranges from 100 to over 140 feet. A crane capacity in excess of 100 tons will probably be needed. Blanket stone, although not nearly as heavy, also requires a crane and boom that can place materials in excess of 120 feet away. A 2-1/2 to 5 CY clamshell attachment

should have no significant problem placing 150 CY of blanket stone per hour. The larger toe stone, however, can probably be placed at a rate of only 75 CY per hour with the same equipment.

3. Armor units will be handled individually and will be moved from a flatbed semitrailer directly to the revetment. The lifting radius required for cranes placing the blocks varies from 30 to 120 feet. Cranes placing the blocks over 60 feet out should be rated at least 100- to 110-ton capacity.

4. Front-end bucket loaders and backhoe excavators can easily place core stone without the use of cranes. A 2-1/2 to 5 CY bucket should have no problem in exceeding the production rate established as the base case.

5. Dewatering could prove to be a significant problem. If sump pumps cannot provide adequate dewatering capabilities, then well points may be necessary.

6. A sheepsfoot roller is the most effective piece of equipment for compacting soil that is high in silt and clay.

Recommendations:

1. The Corps should leave determination of the spoil pile location to the construction contractor, subject to Corps approval.

5.7. Summary

Conclusions:

1. There should be no significant problem in obtaining necessary equipment since the majority of that required is standard in design.

6.1. Construction Sequence

Conclusions:

1. If two work faces are not utilized, then additional shifts or an extensive amount of overtime will be required to complete the project on schedule.

2. Four or five cranes are needed on each work face for stone, armor unit, and pile placement, while an additional one or two cranes with draglines are needed for excavation and backfill.

3. The block revetment will be constructed starting from the toe of the structure and moving upward, with the exception of placement of toe stone, which will occur last.

4. Concrete sheet pile wall section construction should be planned to minimize lateral construction induced loading.

Recommendations:

1. The Corps should leave the actual sequence of construction up to the contractor except in very vulnerable areas. Because of the increased likelihood that overwash can occur at McCabe's Cut and Choctaw Lake, the Corps should require that these sections be constructed first.
2. An additional lane or area should be designated adjacent to the road so that cranes can position themselves off of the primary road and still have access to the material being delivered and the workface.

6.2. Excavation and Shaping

Conclusions:

1. Excavation is perhaps the most critical element in the construction process. This is based on an assumed rate of excavation of 200 CY per hour.

6.3. Geotech Fabric Placement

Conclusions:

1. Contractors at the symposium felt that placement, even underwater, is relatively simple and requires no special equipment.

Recommendations:

1. The geotextile fabric should be preassembled prior to placement if sewing or bonding seams is required so that the number of overlaps is kept to a minimum.
2. Pre-assembled sheets should be overlapped by three feet when installed underwater.

6.4. Pile Placement

Conclusions:

1. It will be necessary to cut or splice piles to achieve a uniform top elevation.
2. Several areas along the trace require extensive site preparation prior to beginning construction. Low sections may require a large amount of fill material and compaction effort.
3. The placement rate for the full sheet pile cross-section (to include armor units, blanket stone, etc.) is estimated at 10 sheet piles per day or approximately 20 feet per day.

Recommendations:

1. If jetting is used, tiebacks should be incorporated into the sheet pile design.
2. A Pre-bid demonstration should be performed during the design phase to help eliminate contractor uncertainties.

6.5. Core Stone/Toe Stone/Blanket Stone Placement

Conclusions:

1. Cranes with a clamshell attachment will probably be used to place the toe stone and blanket stone, while the core stone will probably require a large front-end loader.
2. A 130- to 150-foot swing radius is needed to place toe stone on the typical 1V:5H concrete block revetment section. The swing radius for the crane placing blanket stone varies between 20 and 130 feet.

Recommendations:

1. The Corps should limit the maximum stone drop height in specifications to control possible segregation.

6.6. Armor Stone Placement

Conclusions:

1. Armor blocks will be placed individually.
2. Construction will be a continuous process that takes place in an echeloned sequence. Cranes will maintain approximately the same distance between one another as they advance. Gaps between equipment elements may require adjustment to insure safe operation.
3. Special armor units may be required to maintain the specified gap in transition and closure sections.

Recommendations:

1. Reasonable placement tolerances should be clearly specified in the contract documents. The Corps should ensure that tolerance's specified in the contract documents are essential to project functioning, since most of the structure will be buried or underwater.
2. The placement tolerance for armor stone should not exceed 12-inches between blocks placed underwater. Contractors felt this was acceptable and could be achieved without a great deal of difficulty. Blocks placed above water can be set more accurately if necessary.

6.7. Backfill and Final Grading

Conclusions:

1. Backfilling will be accomplished with a dragline bucket on the GIWW side and with a bulldozer operating on the Gulf side.

Recommendations:

1. Excess spoil material should be uniformly spread on the Gulf side of the structure to provide an additional buffer to help slow down the erosion process.
2. The required amount of site restoration, including vegetation replacement, should be specified clearly in contract documents. In addition, documents should fix responsibility and specify the process for excavating and disposing of contaminated soil which may be encountered or created during the construction process.

8. METHODOLOGY OUTLINE TO ASSIST FUTURE STUDIES

8.1. Introduction

Incorporating construction knowledge and experience early in the planning phase of a project can greatly enhance the project's overall outcome. The benefits obtained from a successful constructability program far outweigh the initial investment costs required for implementation. The CII publication, "Constructability: A Primer" cited cost reductions of between 6 and 23%, benefit/cost ratios of up to 10, and significant schedule reduction (e.g., 14 months on a refinery expansion project) (CII 1986). To help reinforce the benefits, the owner organization for the Sargent Beach Project estimates that as a result of the CII Constructability Study, between $3 to $5 million will be saved on the project. This generates a benefit/cost ratio that greatly exceeds the figure cited in the CII publication. It also provides a motive for similar constructability studies on future projects.

For those engaging in a resource intensive project, performing a logistical constructability study can eliminate a great number of project uncertainties. The information needed to help eliminate these uncertainties can and should be obtained from a variety of data sources. Construction contractors, equipment and material suppliers, owner representatives, and other outside agencies are only a few of the entities that should be queried to help gain valuable information. Unfortunately, the method and sequence in which information is obtained can be somewhat erratic and require a great deal of time.

8.2. Methodology

To help organize constructability efforts, a study methodology is outlined on the following pages. The methodology is similar to that used on the Sargent Beach Constructability Study and is in a logical sequence which can easily be followed.

Prior to initiating any Constructability efforts, commitment from the owner organization must be obtained. Only after the constructability team has full support from the owner organization should the study scope and objectives be developed and agreed upon. To be truly beneficial, it is imperative that the constructability research team fully understand the study objectives and the intent of the owner. Once the study scope and objectives are developed, the research team is capable of organizing it's efforts so that responsibilities are clearly defined and data requirements are identified.

To help define areas of responsibility, the primary constructability categories are broken down into potential areas of concern. The potential areas of concern are established through brainstorming sessions involving the entire study team and should be in line with the owner's objectives. A breakdown of the constructability categories and related areas of concern for the Sargent Beach Project are shown in the affinity diagram in Figure 8. (For more information on affinity diagrams, Brassard (1989).) The three categories within the dotted box represent the logistical areas of concern that pertain to this thesis. The complete diagram should display all the potential areas where constructability efforts could enhance overall project success. Once the major constructability issues are identified they can be assigned to individual parties within the team.

The next step in the constructability study is to attempt to gain an understanding of how the construction process will take place and what tasks are involved. A

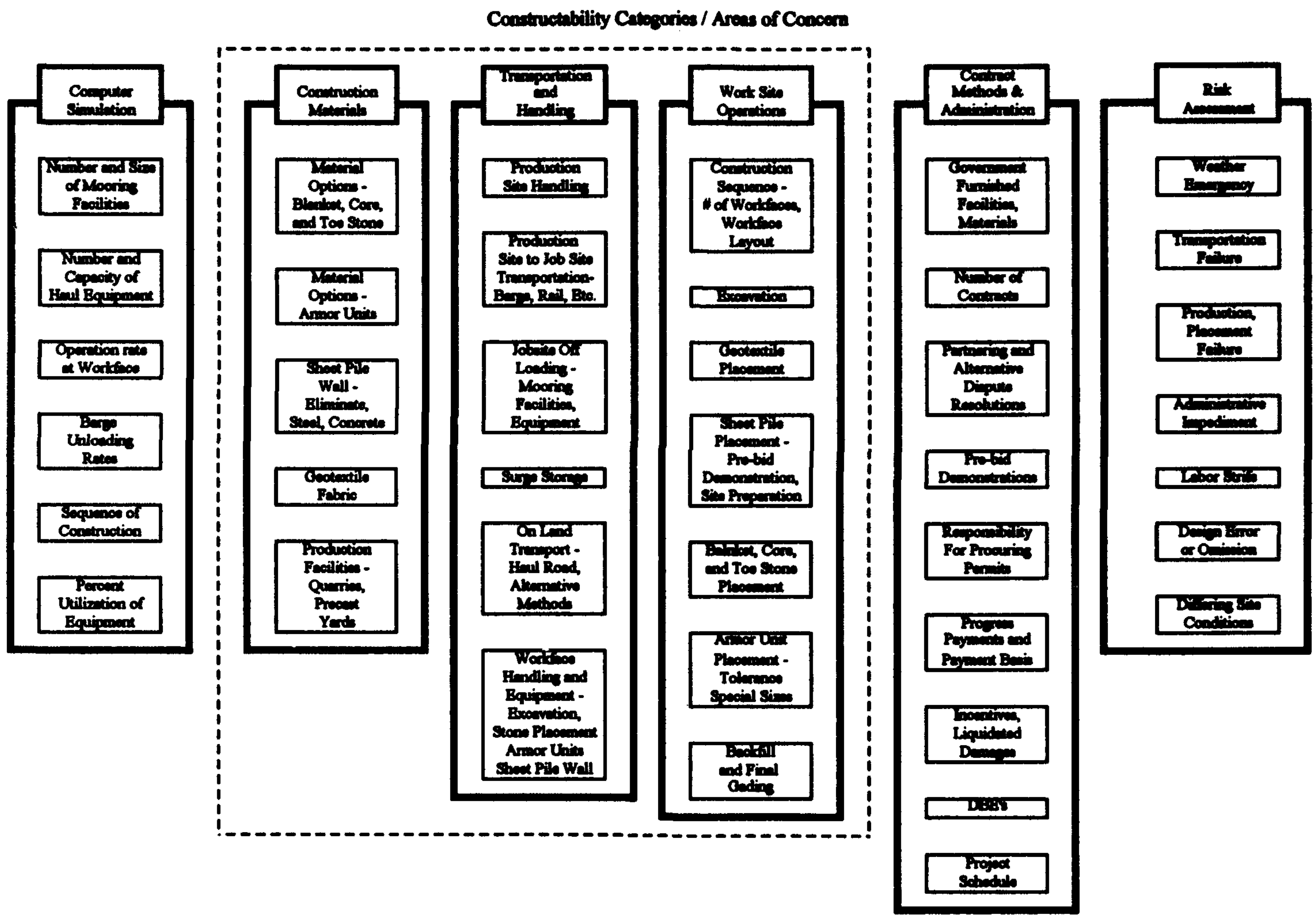


Figure 8. Constructability Categories / Areas of Concern

contractor symposium, similar to the one discussed in section 3.4., is perhaps the most advantageous method of gaining valuable construction data. The contractors or other experts that are invited should be experienced with the type of construction that the project will require (i.e., marine or coastal, industrial, building, etc.), and should be willing to share their constructability expertise in an open forum. By inviting several contractors to the symposium, different viewpoints will be expressed which will help generate alternative construction solutions. This not only helps the research team in gathering construction data, but also assists the contractors by giving them the opportunity to learn more about the project as well as provide design or construction information which may influence the design more toward their liking.

After obtaining data from the contractor symposium, the research team can begin to break down the project into various tasks. The team can use the information from the symposium in conjunction with brainstorming to help identify the major and supplementary tasks involved in the project. The work breakdown structure (WBS) shown in Appendix D provides a detailed breakdown of the three major tasks (mobilization, revetment construction, demobilization) associated with the construction phase of the Sargent Beach Project. The major tasks are then broken down two or three levels so that all of the detailed aspects of the project are considered. Establishing a WBS early provides the research team with a guide to begin their detailed data collection.

By comparing the constructability categories (Figure 8 in this example) with the major and supplementary tasks (Appendix D in this example), the research team participants can easily identify project tasks where they should concentrate their efforts. A simple responsibility matrix is probably the most effective method of displaying which team participant is most responsible for a particular task. Table 3, below, provides an example of a responsibility matrix as it would pertain to the Sargent Beach Project.

Table 3. Matrix for Assigning Project Task Responsibility

	Constructability Categories:					
Project Tasks:	Computer Simulation	Construction Materials	Transportation & Handling	Work Site Operations	Contract Methods	Risk Assessment
Mobilization:						
Admin Actions - Partnering					X	
Establish Precast Yard		X	X			
Construct Mooring Facilities	X		X		X	X
Stage Equipment & Materials		X			X	
Haul Road Construction	X		X	X	X	
Revetment Construction:						
1V:2.5H Revetment Section -						
Excavation	X	X	X	X		
Stone Selection/Placement	X	X	X	X		
Armor Units Placement	X		X	X		
Sheet Pile Wall Section -						
Pre-bid Demonstration				X	X	X
Set and Drive Sheet Piles	X		X	X		X
Place Stone Gulf/GIWW	X		X	X		
1V:5H Revetment Section -						
Dewatering Process				X	X	X
Demobilization:						
Site Restoration				X		

The areas denoted by a boldface X represent the areas of responsibility that pertain to this thesis. (For information on the contracting methods and risk assessment constructability categories, see Flanigan (1993).)

Although the matrix is not all inclusive, it does provide a good representation of how the various tasks are assigned to the team participants. It is apparent that some tasks are so broad that they fall into several of the constructability categories. This indicates that two of more of the study team members should combine their efforts and share the data they obtain from their various sources. This will most likely result in a more effective outcome requiring fewer man-hours.

As areas of responsibility become better defined, study participants should start developing a list of data requirements pertaining to their assigned areas. The list is a working document that is continually updated, depending on the amount of detail required. In order to fulfill the data requirements, the study team members should identify several knowledgeable data sources who can help provide constructability expertise. Maintaining contact with the contractor representatives who attend the symposium is the best place to gain additional information. Their vast knowledge in construction will assist in answering many questions. For those areas in which the contractors have little experience, they can probably provide assistance obtaining additional sources of information or points of contact with expertise in that particular field.

Although the contractors are capable of fulfilling many of the data requirements, it will probably be necessary for the study participant to identify additional sources. Operators of quarry sites and precast yards can provide reliable information pertaining to material quality requirements and production rates as well as the transportation and handling requirements needed for the material. Equipment specialist (dealers, operators, etc.) can answer questions relating to equipment capacities and cycle times. Transportation information can be obtained from state highway departments (i.e., Texas Department of Transportation) or the Corps of Engineers can be queried for information dealing waterway traffic (i.e., Gulf Intracoastal Waterway). Project construction site visits are another valuable source of information. If the participants can actually see the location where construction is to take place, they have a better appreciation of the area conditions and construction limitations.

Throughout the entire study process it is extremely important to conduct coordination meetings on a regular basis, preferably every two weeks. The meetings provide the team members an opportunity to share information and discuss progress as well as help to eliminate duplication of effort. During the constructability period, it is also critical for the Study Director to maintain open communications with the owner organization to ensure that the constructability study is fulfilling the owner's objectives. It is helpful to provide the owner organization with a copy of the rough draft once it is prepared so that any final project updates or revisions can be implemented to the final report.

Although not all inclusive, the following list of steps is provided to help summarize the methodology involved in a constructability study:

a. Obtain commitment from the owner organization.
b. Develop and agree upon the study scope and objectives.
c. Organize the study team (ensure intent of the owner is understood).
d. Establish constructability categories and areas of concern through brainstorming sessions (affinity diagram).
e. Assign categories to participants based on areas of interest.
f. Gain understanding of construction process (contractor symposium).
g. Identify the major and supplementary project tasks (work breakdown structure).

h. Compare the constructability categories with the project tasks to help assign responsibility (responsibility matrix).
i. Develop detailed list of data requirements.
j. Identify and query knowledgeable sources of information.
k. Conduct site visits (project construction location).
l. Write the report.
m. Share results.

A graphical representation of the constructability steps is shown in Figure 9. This roadmap helps to identify which entity is responsible for a particular task or activity. The rectangular boxes represent the task or activity, whereas the diamond denotes an area that requires a decision. The circular shape with an adjoining line displays an activity where more than one entity is involved and shows that input or assistance should be obtained from that particular entity under which the circular shape is shown. The small case letter (i.e., a., b., etc.) corresponds with the list of steps previously noted.

8.3. Discussion

The methodology described in the previous section only provides a simplified outline and is not all inclusive. However, it does provide a guideline by which a constructability team can get started and follow during their research. The Sargent Beach Constructability Team followed a similar methodology. However, the team's approach was not as structured. For instance, the Sargent Beach Team did not develop their work breakdown structure until well into the study. This did not cause a major problem, but it was apparent that several of the team participants had different viewpoints of how the construction process was going to take place. Fortunately, the biweekly meetings conducted by the Study Director helped to clear up any confusion.

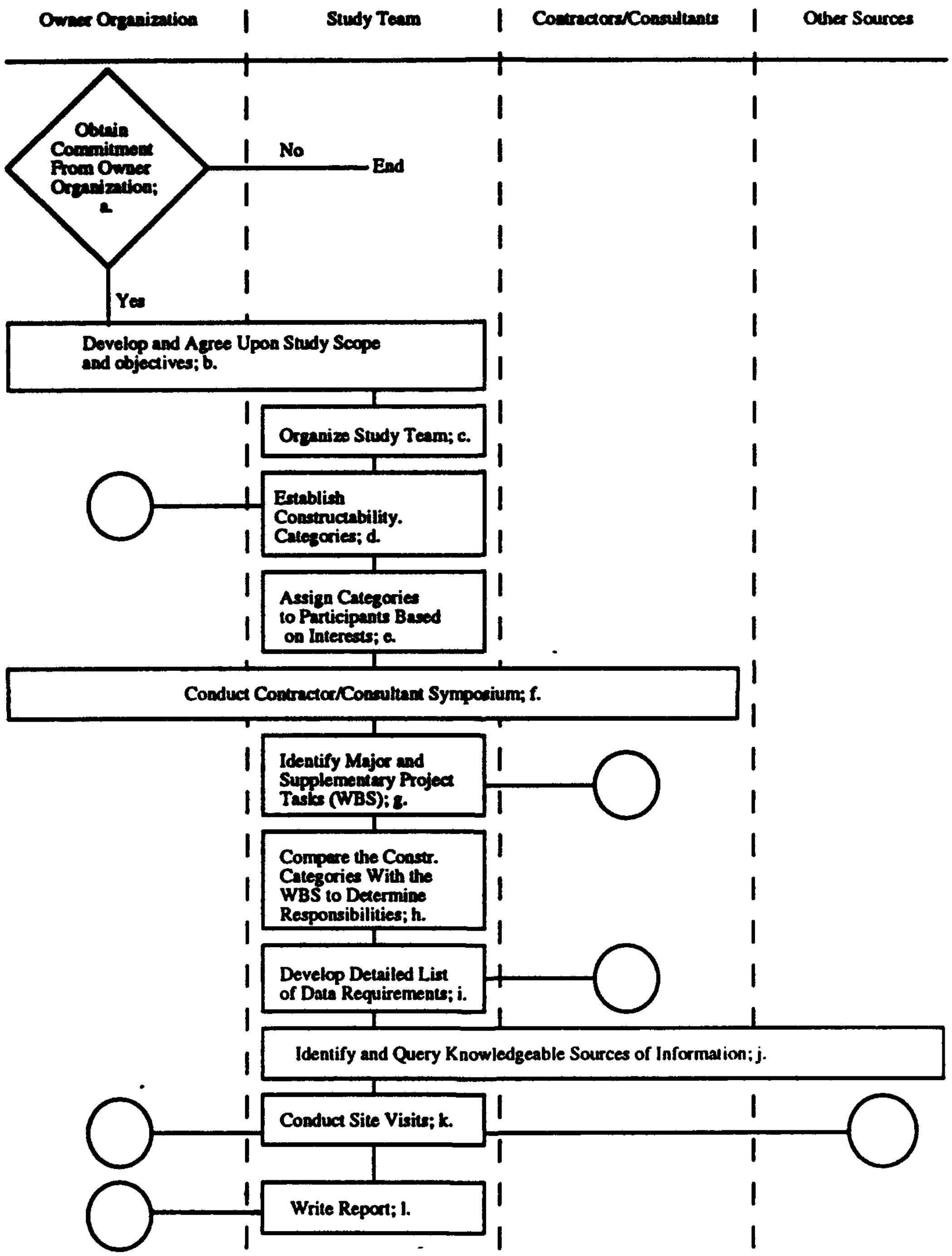


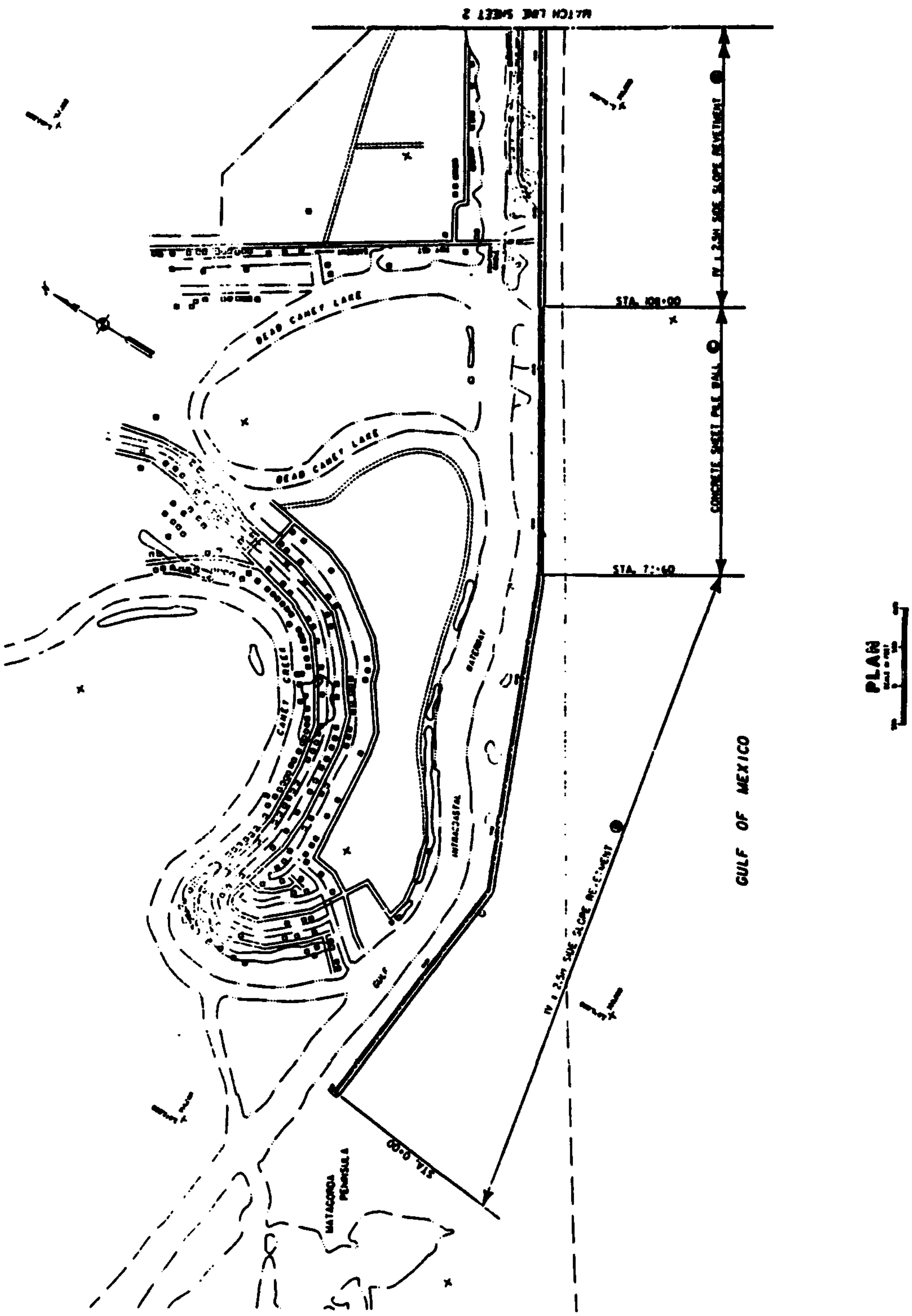
Figure 9. Roadmap for Conducting Constructability Studies

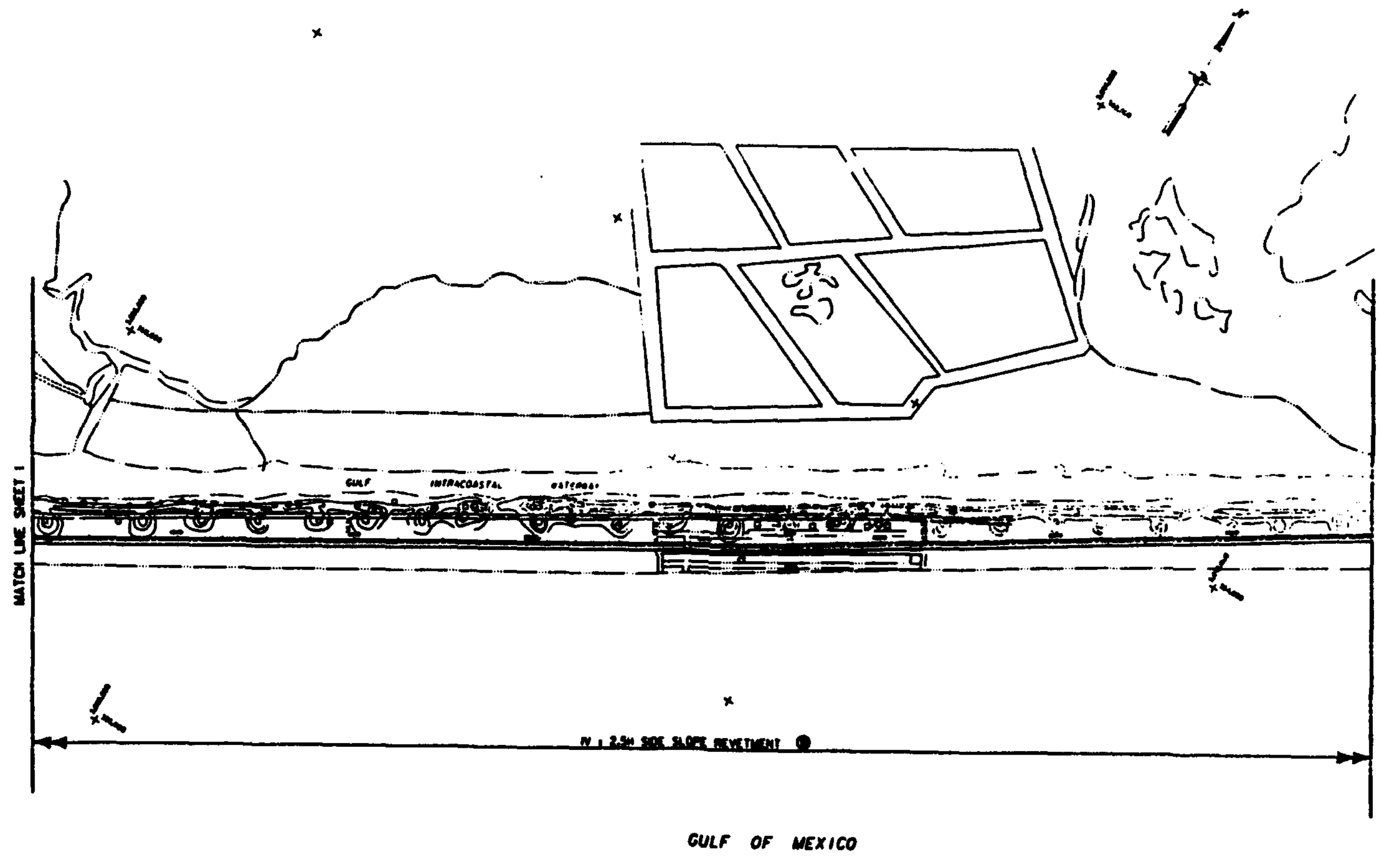
Perhaps the most important aspect of the constructability study, which is strongly encouraged for all future studies, was the contractor symposium. It provided the majority of the information contained in the study report, as well as this thesis. By conducting the symposium early in the study process, the team was able to use the data as a basis for the remainder of their research. Construction methods and sequences, likely material sources, transportation limitations, and other valuable constructability data were all obtained at the symposium.

The study appears to have been extremely beneficial from the standpoint of the Corps of Engineers and is definitely an endeavor worth pursuing again. During the study, the majority of the information sources were very helpful. This was probably because an outside, impartial organization (CII) was performing the research. In the future, some form of constructability program should be adopted by the Corps of Engineers which enables them to perform similar studies on other large projects.

APPENDICES

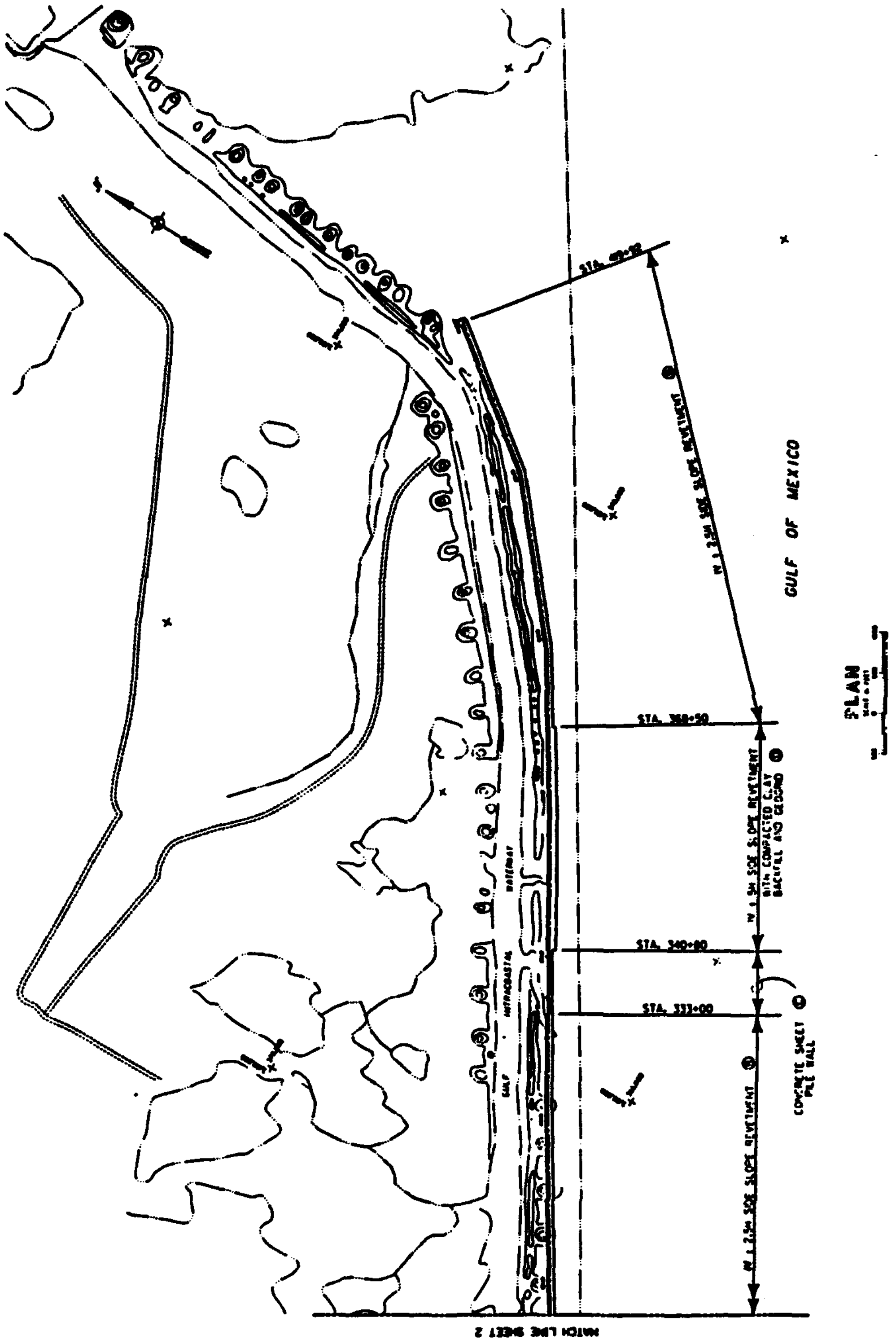
Appendix A: Plan View of Structural Trace





MATCH LINE SHEET 1
MATCH LINE SHEET 3
GULF INTRACOASTAL WATERWAY
1V : 2.5H SIDE SLOPE REVETMENT
GULF OF MEXICO

PLAN


GULF OF MEXICO
PLAN
STA. 368+50
STA. 340+80
STA. 333+00
GULF INTRACOASTAL WATERWAY
MATCH LINE SHEET 2

Appendix B: Questions for Sargeant Beach Constructability Symposium:

Materials

1. Where are the potential (most economical) source locations for: (In state/Out of state)
   A. Core stone
   B. Blanket stone
   C. Armor Units
   D. Concrete aggregate
   E. Road Material
   F. Rail Material

2. Is concrete block definitely the option over quarry stone? If not what are the potential sources for quarry stone?

3. Is precast concrete preferred over establishing a batch plant? If not see question 4.

4. Is it feasible to establish a batch plant on the island? On mainland closer to the aggregate sources or closer to the transportation source (mooring facility, port, rail)?

5. What is the estimated production rate for a precast delivery or concrete batch plant?

6. What is the production/delivery rates for blanket/core stone?

7. Can placement rates maintain an equilibrium with delivery rates? If not, where and how much storage should be maintained within a staging area?

8. What is the cost of developing/establishing a batch plant on the island/closer to the aggregate source?

9. Is a geotech fabric necessary for this project (blanket stone)? Which geotech fabric would be most effective (source)?

10. What grade should the blanket stone be (well graded, poorly graded, etc.) if a geotech fabric is used? If not used?

11. Where are the possible sources for the concrete sheet pile?

12. What is the cost and production rate for the concrete sheet pile?

Transportation and Handling

1. What transportation/access assets do the supply sources have available to them (rail, road, port)?

2. What is the cycle time from the supply source to the construction site or batch plant?

3. What is the most feasible means of transporting these materials on the mainland, water, and island?

Possibilities:

A. Load materials on rail at source location, put rail on barge or bridge and establish rail system on island for unloading (only handle material 2-times, loading and unloading).

B. Load materials on flat bed trucks - either barge or bridge GIWW and establish roadway system for unloading (only handle material 2-times, loading and unloading).

C. Establish channel adjacent to structure alignment, therefore allowing unloading directly from the barge.

4. How many mooring facilities should be constructed? At what locations would the mooring facilities be most efficient?

5. What is the estimated cost and duration for constructing:
   A. Rail (8 miles)
   B. Reliable road network
   C. Channel adjacent to structure alignment
   D. Mooring facility (1 or 2)

6. What additional resources/information is necessary to construct (A-D) above (i.e., ground compaction, foundation requirements)?

7. What accessibility do we have to barges/rail/trucks (rented, owned, contracted)?

8. What necessary measures must be taken to gain access to GIWW (barge schedule delivery, swing bridge, rights of way)?

9. What is the necessary equipment (type, #) needed for loading and unloading at the source location, construction sites, port or mooring area, and batch plant?

10. What are the barge regulations and requirements for hauling rail, trucks, and loose rock?

11. What ports/facilities will most likely be used (if any)?

12. Are there adequate rail facilities to load rail on barges at the recommended port facilities?

13. What is the load (weight, size) capacity of a rail car/flat bed truck/barge for blanket and core stone, concrete aggregate, and armor units?

14. What staging areas are necessary? What should be the size and location?

Work Site Operations

1. Is it necessary/advisable to dewater the excavated area during placement of materials (geotech fabric, blanket and core stone, armor units)?

2. If dewatering is not necessary what information or considerations should be taken into account? If dewatering is suggested, what method (equipment) should be used for the operation?

3. What equipment is necessary for excavation, placement, and backfill operations?

4. What is the recommended method of excavation (dozer, dragline)?

5. How should the construction process take place?
    - A. Clear and mark structure alignment
    - B. Excavation
        1. Construction in water / Dewater
        2. Spoil placement
    - C. Geotech fabric placement (if used)
    - D. Blanket stone (core stone) placement
    - E. Armor unit placement (precast or batch plant)
    - F. Backfill (grade)

Should all of the above processes take place concurrently (broken down into sections)?

6. Where should construction work start first (McCabe Cut, Choctaw Lake)? How many locations should work be taking place concurrently (# of contracts, one contractor)?

7. How much ditch should be open/excavated at any given time (one mile, entire length)?

8. How should the revetment/sheet pile operation take place (order of work, production/placement rates, necessary equipment, crew size, work area required both landward and seaward side, other considerations)?

9. How should the sheet pile be placed (driven poured in place, excavated, etc.)?

10. How much materials should be stockpiled on the island? How much spoil should be stockpiled at one time?

11. What are the risks associated with storing/stockpiling materials on the island (weather/storm damage)?

12. In what sequence should the structure be constructed?

A. Entire blanket stone layer prior to armor stone placement?

B. Work from toe upward or splash apron downward?

13. What additional support facilities are necessary on the island (helicopter pad, roadway, water availability, latrines, emergency equipment, hospital/first-aid facility, eating facilities, sleeping requirements, etc)?

14. What are the most serious potential choke points?

Appendix C: Constructability Symposium Meeting Minutes

MEMORANDUM FOR RECORD

FROM: John E. Wood and W. Scott Flanigan

DATE: 9 March 1993

SUBJECT: Constructability Symposium For The Sargent Beach Study, 12 Feb. 1993.

1. The purpose of this memorandum is to document the results of the constructability symposium held at the Houston Intercontinental Airport Marriott Hotel, San Jacinto Room, on Friday 12 February 1993 from 0800 - 1600 hours concerning the Sargent Beach Constructability Study.

2. Those in attendance at the meeting were:

Name	Company	Telephone #	Address
MG Charles McGinnis	CII	512-471-4319	3208 Red River St. Suite 300 Austin, TX 78705
Dr. Koshy Varghese	Univ. of Texas / CII	512-471-1620	Dept. of Civil Engr, ECJ 5.200, Austin, TX 78712
Cpt Scott Flanigan	Univ. of Texas	512-471-4648	Dept. of Civil Engr, ECJ 5.200, Austin, TX 78712
Cpt John Wood	Univ. of Texas	512-471-4648	Dept. of Civil Engr, ECJ 5.200, Austin, TX 78712
Mr. Curtis Stefferud	Univ. of Texas	512-471-1620	Dept. of Civil Engr, ECJ 5.200, Austin, TX 78712
Mr. Hatem Goucha	Univ. of Texas	512-471-4648	Dept. of Civil Engr, ECJ 5.200, Austin, TX 78712
Mr. John Cleveland	Corps of Engineers	409-766-3089	PO Box 1229 Galveston, TX 77553
Mr. Mike McClenan	Corps of Engineers	409-766-3977	PO Box 1229 Galveston, TX 77553
Mr. Richard Tomlinson	Corps of Engineers	409-766-3171	PO Box 1229 Galveston, TX 77553
Mr. Mike Villeneuva	Corps of Engineers	409-766-6377	PO Box 1229 Galveston, TX 77553
Mr. Jim Van Norman	T.L. James & Co. Inc.	713-452-3373	PO Box 956 Channelview, TX 77530
Mr. Steve Spohrer	T.L. James & Co. Inc.	504-461-9356	PO Box 20115 New Orleans, LA 70141
Mr. Frank Denton	T.L. James & Co. Inc.	504-461-9310	PO Box 10 Kenner, LA 70063
Mr. Harlon Fowler	Brown & Root, Inc.	713-676-7481	PO Box 3 Houston, TX 77001
Mr. Harold Horne	Brown & Root, Inc.	713-676-4638	PO Box 3 Houston, TX 77001
Mr. Dana Strebeck	Brown & Root, Inc.	713-676-4209	PO Box 3 Houston, TX 77001
Mr. William Gardner	Luhr Bros., Inc.	618-281-4106	PO Box 69 Columbia, IL 62236
Mr. William Shaw	Luhr Bros., Inc.	618-281-4106	PO Box 69 Columbia, IL 62236
Mr. Jack Seward	Luhr Bros., Inc	409-233-2224	PO Box 937 Freeport, TX
Mr. James Stockstill	C.F. Bean Corporation	504-391-7000	PO Box 237 Belle Chase, LA 70037
Mr. Glen Ashy	C.F. Bean Corporation	318-234-4501	PO Box 51657 Lafayette, LA 70505
Mr. Yale Lyman	Guy F. Atkinson Co.	415-876-1328	10 W. Orange Ave. S. San Francisco, CA 94080
Mr. Stephen Maynard	H.B. Zachry Co.	713-933-9993	PO Box 722250 Houston, TX 77272
Mr. Wayne Sutherland	Morrison Knudsen	208-386-5000	PO Box 73 Boise, ID 83729

3. MG McGinnis started the meeting at 0800 hours with welcoming remarks and brief introductions of the CII/University of Texas research team. The floor was then open for each individual attending the meeting to briefly introduce themselves and state which company they were representing and what position they held.

4. MG McGinnis discussed the purpose of the meeting and what products he hoped would result from the symposium. He then reviewed the meeting agenda and asked for any suggestions to improve the meeting plan (no suggestions were given).

5. MG McGinnis then presented a project briefing, in the form of a slide show, to those in attendance. The slide show provided a good overview of the project area and gave a good explanation of why the study is important. The design features of the revetment and sheet pile wall were briefly discussed as well as the addition of the geotextile fabric.

6. MG McGinnis asked for any questions concerning the project briefing slide show. The following questions were asked:

Q1: How was this project selected by the Corps of Engineers (COE)?
A1: This project seems to have good potential for the application of constructability concepts and the ability to try new concepts.

Q2: What is the availability of sand for beach renourishment?
A2: Beach renourishment was considered in the feasibility study and was found to be too expensive.

Q3: The COE used a similar design on the Spillman Island Project (vic. Houston); however, they used quarried rock in a rubble effect instead of armor units. Why not use a rubble design on this project?
A3: The design of the armor units has undergone testing at the Waterways Experiment Station and found their size and density to be most effective given the life of the project (50 years). The shape and weight of the armor stone provide the stability needed to undergo the constant wave action from the Gulf. With graded quarry stone there is a high likelihood that the wave action would move or damage the protective structure.

Q4: Why construct the revetment only 300 feet from the GIWW?
A4: 300 feet is the minimum buffer which must be maintained between the GIWW and the Gulf. If construction were to take place closer to the Gulf, unexpected storms could increase erosion rates and affect the project by making construction take place

under wet conditions (i.e., wave action). The objectives are to protect the GIWW and permit construction to take place under the most favorable conditions possible.

7. Following the introductions and project briefing, the discussion shifted to the agenda items in order to gain feedback from the contractors on the proposed design.

8. Issue: **Sources of Core and Blanket Stone**

a. St. Genevieve or Cape Girardeau, Missouri are possible sources for the core and blanket stone. Several other sources exist along the Ohio River as well. Projects in the southeastern US and Gulf Coast region rely primarily on these sources.
b. The gradation of the stone has not been a significant concern in the past; the majority delivered is within the specifications needed. The type of stone delivered is predominately dolomite.

9. Issue: **Sources For Stone Armor Units**

If a quarry stone is used for armor units, then the most probable source to meet the granite size requirement is Marble Falls, Texas. The granite at that location usually ranges from 4-6 tons; therefore, the required 6 ton armor unit is at the upper limits of the scale. This alternative might not be cost effective and will probably not be able to compete against the precast concrete option.

10. Issue: **Equipment For Handling The Armor Units**

a. For the large granite a rock grapple weighing 3 - 5 tons will work effectively.
b. For the precast concrete units, a lifting eye might be precast into the unit, therefore allowing the unit to be picked up by a crane. A rock grapple can also be used effectively with the concrete units.

11. Issue: **Acceptance/Rejection Criteria For Armor Units**

a. It is to be expected that the armor units, be they stone or precast concrete, will be knocked around somewhat during shipment and placement, and that some chipping, cracking, or other damage will occur. A significant concern was that reasonable acceptance/rejection criteria be established. Unreasonable criteria will significantly increase the cost of the project.
b. The Corps is more concerned with functionality than appearance, since the majority of the units will be buried initially. A reasonable standard for surface finish of the revetment would be +/- one foot. A smaller tolerance (1-6 inches) would be difficult to meet and would increase costs significantly.

c. The critical issues which should be addressed in the contract documents include the acceptable levels of damage which the armor units can undergo before rejection and the grade control for stone placement.

12. Issue: **Construction Using Floating Equipment (i.e. the "Wet Method")**

a. One construction method considered involved cutting access channels from the GIWW into the middle of the island, making the required excavations using dredging equipment, and placing the core and blanket stone and armor units directly from the barges used to transport them to the project site. This method came to be called the "wet method" for building the project, since construction would be done largely underwater using floating equipment.
b. One contractor felt that by taking the material directly off the barge and placing it into final position, the handling and installation costs could possibly be reduced by half.
c. The channel would be excavated with the use of floating dredge equipment. A bucket dredging apparatus would operate directly off a barge and would place the excavated material on the Gulf side of the structure.
d. The rock barge has an average dimension of 35 feet wide by 195 feet long and requires a 9 foot draw. The barge used for the unloading equipment has an average width of 40 feet and requires a 5 foot draw. Therefore, the channel cut would require a minimum width of 80 feet and might be as wide as 100 feet.
e. If a channel were to be dredged for barge traffic, then the 300 foot ROW would probably have to be expanded.
f. If this method of construction is permitted (excavated channel cut), then the contractor should be given the freedom to choose how the excavation should take place, as this might help generate competition. All too often a contractor's hands are tied as to the method of construction because of procedural specifications.
g. If a channel cut is used to deliver materials and construct the structure, then additional access channels may be needed from the GIWW. It was recommended that the channel have an access cut every 2500-5000 feet with a width of 60-70 feet. If this plan is selected, there may be significant real estate implications.
h. If access channels are cut, then they must be closed using sheet pile or some type of revetment design. It may require a revetment which has stone slope protection on both sides (trapezoidal design).
i. Some of the problems associated with this method include real estate acquisition for rights-of-way, and the possibility of cutting the access route to existing houses. It was recommended that the existing road remain intact and that access channels be provided at either or both ends of the road.

13. Issue: **Location of Concrete Casting Yard**

a. No consensus was reached as to whether the prime contractor would set up his own casting yard for manufacture of precast concrete armor units or use existing precast plants as suppliers.
b. The contractors agreed that the only economical means of transporting the precast armor units would be by barge.
c. The consensus was, then, that the casting yard would be located in the vicinity of an existing port, such as Freeport or Houston, regardless of who was running it, prime contractor or supplier.

14. Issue: **Methods of Manufacturing Precast Armor Units**

a. The cheapest method is to place the concrete in a form on a base and ensure that a lifting device is included. The types of lifting devices might include a lifting eye, wire loops, or the most preferred method, a hole placed all the way through the concrete with a pipe. This will allow for lifting during future maintenance operations, as opposed to a lifting eye which will eventually corrode.
b. The 6 ton armor units should have a recommended strength of 3500 psi and should contain sulfate resistant cement. The armor unit specifications should be of standard design with no exotic cement requirements.
c. In general, the contractor should have the ability to use admixtures, superplasticisers, or whatever method current technology has introduced as long as it meets the design specifications.
d. The aggregate used in the concrete armor blocks should be commercially available, preferably the standard 2 inches and below. It was also suggested that the concrete should have hard stone in it to prevent possible erosion from the salt/sea water. Typical river run rock should be sufficient for the concrete with a suggested source located in Victoria, or anywhere along the Colorado River.

15. Issue: **Sources For Concrete Sheet pile**

A possible source for concrete sheet piling is Texas Concrete.

16. Issue: **Design of Service Road**

a. River run stone will probably work effectively. Builders of similar roads in Louisiana are finding crushed limestone to work best. A geotextile fabric should be incorporated into the service road design.

b. The road should be designed wide enough to handle truck mounted cranes with outriggers employed, since it is assumed that these cranes will be needed for periodic maintenance or repairs on the revetment.
c. It was suggested that the splash apron be extended enough to construct the service road right on top. The splash apron blocks could be choked with additional limestone.

17. Issue: **Curing Time and Specifications for Precast Blocks**

a. The length of time that precast concrete armor units must cure before they can be moved should be left to the contractor's discretion. The contractors prefer performance specifications so as to have maximum flexibility to use new techniques. The contractor wants to know what the block should look like and any other mandatory design requirements (COE responsibility); then let them handle the details on how to construct and move the armor units.
b. Since the majority of the blocks will be buried, finishing or texturing on the block will probably not be required. If texturing is required, procedural specifications are not necessary; the costs associated are relatively small.
c. Special block sizes will probably be needed in transition areas adjacent to sheet pile sections, and possibly also when closing gaps between two work faces.

18. Issue: **Stockpiling Construction Materials**

a. The contractors did not think that this project could be done using just-in-time delivery of the materials; the distances the materials will be traveling and the number of things that potentially could interfere with timely delivery make that approach too risky. Stockpiling materials on site is one means of managing the risk of transport failure, and will be required to some extent.
b. If materials are delivered and unloaded directly off barges, then extra barges can be kept on site to handle stockpile requirements. The "demurrage" limit is 3-4 days at the destination. To control the delivery process, a river control point will be established and barges will arrive about 5-6 at a time.
c. If unloading does not occur directly off the barges, then a storage site will have to be constructed, as the existing soil strength is inadequate for large storage loads. The storage location will require stone to be brought in from outside sources.
d. The 300 foot ROW should provide sufficient area in which to store materials.
e. The contractors prefer to determine their own site locations for materials storage along the length of the revetment ROW, rather than having this dictated to them by the COE.
f. The contractors recommend a 3-4 day supply of materials to be stockpiled at the site. Therefore, wherever the storage location(s) are constructed, they must be capable of holding approximately 300-400 armor units (Dr. Varghese estimated that 70-80

blocks would need to be placed per day), and nearly 20,000 tons of rock (blanket and core stone). The armor units will be stored 1 block high, possibly 2.

19. Issue: **Spoil Disposal**

a. Although excavated material should not pose any significant problems, it should still be addressed in the contract. In the past, the majority of the excavated material goes right back in the hole with very little excess.
b. Excavated material should be stored on the beach (Gulf) side of the structure.
c. It was recommended that the extra backfill simply be graded level so as to provide additional material to help slow down the erosion process.

20. Issue: **Use of Geotextile Fabric**

a. Although not shown on the plans included in the read-ahead packet, geotextile fabric will be used on the project.
b. Transport and procurement of an effective geotextile fabric is not a significant issue since it is an "off-the-self" item, and it can be easily emplaced. Geotextile fabric placement will not be a significant schedule factor during construction.
c. The geotextile fabric comes on a large spool and can be rolled out like a carpet.
d. Overlapping the geotextile fabric at the edges should be sufficient, and much less costly than sewing the adjoining sheets together.
e. In the rolled clay sections, a geotextile fabric is preferred over other methods of soil stabilization such as lime or cement.

21. Issue: **Sheet Pile Wall and Pile Caps**

a. The preliminary design calling for the use of concrete sheet piling generated much heated discussion and considerable concern on the part of the contractors present.
b. The contractors questioned the use of concrete sheet piling instead of steel sheet piling. The proposed design calls for the use of concrete sheet piling instead of steel sheet piling because the COE does not have enough confidence in the life expectancy of steel or coated sheet pile; it is thought that concrete sheet pile will last longer. Aesthetics is a minor factor as well.
c. The COE envisions that the concrete sheet pile wall will be driven first, and then the ground can be excavated to install the toe protection. Many contractors expressed doubt that the piles would stay up without tiebacks. Since the wall is cantilevered and not tied back, surcharging from the GIWW side could cause the wall to collapse unless it is driven deeper. The contractors found the requirement to excavate 14-15 feet below ground, after driving the piles, in order to emplace the blanket stone, core stone, and armor blocks, particularly worrisome. The precise excavation required in

the vicinity of the piles would be very time consuming and add significantly to the project cost.

d. Several contractors felt the wall would prove to be extremely costly; another method or design might prove more feasible. Perhaps the stone revetment with a flatter slope and geotextile fabric can replace the sheet pile wall. One representative stated that greatly increasing the amount of stone used or somehow strengthening the soil in the areas of poor foundation conditions was greatly preferred over the concrete sheet piling solution, and that use of concrete sheet piling could conceivably add $2 million to the overall project cost.

e. A precast pile cap will be much cheaper than a cast-in-place cap, and should be considered.

f. If a cast-in-place concrete pile cap is needed, then a batch plant can be set up on a barge and water brought in from an outside source if it is not available on the island.

g. The question was raised as to whether or not the pile cap would require reinforcement, without a definitive answer being given.

h. Given their doubts about the proposed design, the contractors expressed a preference for procedural specifications for the sheet pile wall sections. They felt that this would put the risk for this portion of the work on the COE.

i. Several contractors stated that it was unreasonable to expect that all piles would be driven to the same toe elevation. It is to be expected that some would have to be driven to a lesser depth and then cut off.

j. A slurry wall was not considered a feasible alternative.

k. Several contractors stated that they felt that it may be necessary to jet the concrete piles, and that this would impact on the design. Tiebacks would be required if jetting is necessary.

l. The contractors identified the concrete piling as a potential significant problem area once work got underway and also as a potential source of disputes and claims.

22. Issue: **Materials Transportation Options**

a. Rail-barge-rail or Rail-piggy back barge-rail: When moving a rail car on a barge, the costs increase significantly because payments are required for both the rail car and the barge. In this situation, the barge is "hauling iron and not rocks." Also, the soil conditions would make it extremely difficult and costly to construct a railroad on the island. Wadsworth is probably the nearest rail facility, and it has limited accessibility by water. The general consensus was that this method was not feasible unless alternate means were prohibited.

b. Barge-direct unloading using excavated channel cut: The location of this project makes it extremely advantageous to use water transportation rather than rail whenever possible. It is much cheaper than rail and is more reliable. In addition, the use of water transportation helps reduce material handling requirements. Barges are capable of delivering the blanket and core stone to either a terminal site or directly to an unloading zone along the channel cut. Armor units would also most likely be transported this way. In addition, if barges are used for direct delivery and construction, then the barges can be used for storage until the material is ready for placement.

c. Swing bridge use: The use of the swing bridge cannot be relied upon. The tide affects the swing bridge and the bridge interferes with traffic on the GIWW when employed.

d. Truck usage: Trucks will be used on the island for some material delivery, but this issue was not discussed in detail. It was mentioned that on previous projects, truck traffic was ruled out because of noise and bureaucratic restrictions. The contractors expressed concern about any such restrictions that would be placed on them on this project. If there were to be restrictions, they emphasized the need to ensure that they were explicitly stated in the bid documents, otherwise this would be a certain source of claims. Restrictions on truck use on the island are not anticipated at this time.

e. The contractors felt there were no significant complications in moving materials from the source location (i.e., quarry) to the island or barge terminal. The suppliers are reliable and deliver large quantities of rock and stone to this area (Gulf region) on a regular basis.

23. Issue: **Barge Terminals on the Island**

a. One contractor stated that barge terminals would not be necessary if excavated channel cuts are used to deliver and construct the structure; the remainder, however, felt that barge terminals on the island would be needed. The general consensus was that a minimum of 1 terminal should be constructed for each contractor, with the optimum number of terminals being 2 (even if using only 1 contractor). Two terminals will assist in the construction and provide some redundancy in the event one of the terminals were closed due to an accident (a sunken barge at the terminal, for example).

b. If more than one contractor is used on the project, then each contractor should be provided with his own terminal or terminals. It is unrealistic to expect that contractors would share a terminal. Use of shared terminals would increase the COE's burden in scheduling their use and would be a likely source of claims.

c. The average raft has 6 barges and each barge has an average dimension of 35 feet by 195 feet. Therefore, the proposed 50 by 450 foot terminal must be increased in length. The recommended length for the terminal is 800 feet. The proposed 50 foot width of the terminal may not be large enough either. The width of the barge terminal may have to be increased to 80 feet. Another option that would require investigation is to anchor barges on the GIWW, but outside the navigation channel.

d. If terminals are to be constructed, the COE feels that two would be needed on the island. The terminals may be required for future COE operation and maintenance purposes. If the terminal(s) is strictly for the COE's future operation and maintenance needs, then that should be so stated in the contract documents, because the construction contractor may not plan on using a terminal if they are using the excavated channel cut (wet method).

e. There are basically two options for construction of barge terminals on the island: 1) include terminal construction in the scope of the main construction contract, or 2) let a separate contract prior to awarding the main construction contract. Although separate contracts may result in a higher overall cost, the majority of the contractors felt that it would be advantageous for the Corps to issue a separate contract for the terminals and ensure that they are complete prior to awarding the construction contract. The only risk associated with early construction of the terminals is the possibility that they are not complete when the main construction contractor is prepared to begin work. It would be ideal to incorporate terminal construction into a GIWW maintenance dredging contract; however, dredging timing may preclude this.

24. Issue: **GIWW Requirements/Limitations**

The average speed allowed on the GIWW was estimated at 4-5 mph. Traffic control and wake wash were discussed as possible issues to investigate further. The Coast Guard requires that barges not be left unattended at any time. The Colorado River locks on the GIWW may have a difficult time handling a 6-barge raft.

25. Issue: **Equipment Availability**

No problems are foreseen regarding the availability of equipment (i.e., barges, cranes, etc).

26. Issue: **Off-Loading (Dry Method, No Channel Cut)**

a. A rock drag bucket will be used for large materials, while a conveyor system will move the smaller materials into trucks or a storage bank.

b. The trucks used for transport will probably range in size from 25-30 tons (i.e., DJB). Once loaded, the truck will transport the material to a storage area or directly to the site for placement.

c. The storage location will require a crane for loading and unloading.

27. Issue: **Number of Contracts**

a. The general consensus was to recommend one contract. No one said they would <u>not</u> bid the job if it was let as one contract.

b. Use of two contracts would require separate docking facilities, and could cause conflicts with casting plants and quarries. Use of one contract would eliminate the problem of competing for facilities, as well as eliminate that as a potential source of claims or disputes.
c. The expectation is that all the companies involved in the bid process would bid both contracts if two contracts were let.
d. If the Corps chooses to go with two contracts, they should let them separately, at different times. However, the contractor who had won the first contract would be at a significant advantage over other bidders for the second contract.
e. Two contracts would significantly increase the amount work required by the Corps.

28. Issue: **Work Faces**

a. The contractors prefer to operate only one work face at a time. They would operate two work faces probably only if the schedule required it.
b. The closure between 2 separate contracts/work faces could be difficult and would require good coordination between designers, contractors, and project managers. Special size armor units may be required to provide proper closure. The transition between the sheet pile wall and the revetment may also require a special block design.
c. If the schedule required that two work faces be used, the contractor would probably start in the middle and work outward.

29. Issue: **Excavation and Stone Placement**

a. Excavation will probably be on the critical path because of the large volume of soil that must be excavated (approximately 1.2 million cubic yards).
b. The excavated face should be left open for as short a time as possible. The open face is extremely vulnerable to storms and could result in a break through.
c. On other projects, the COE has used closure specifications which place limitations on the distance and time which an excavated face can remain open. The distance is believed to be 200-300 feet. Unless this specification can be changed, it might have serious implications on the excavated channel method (wet method).
d. To minimize risks, it was recommended that the distance between the head of the excavation and the placement of the armor units be minimized.
e. The specifications for layer placement distances were believed to be 200 feet for blanket stone and 500 feet for toe protection. Toe protection will be the last item placed during the construction sequence.

30. Issue: **Work Conditions (Wet or Dry)**

a. Most of the work is expected to take place under wet conditions (i.e., below a free water surface).
b. In order to conduct construction in the dry, wellpointing may be required.
c. The rolled clay section will require dewatering and could prove to be expensive. Since the elevation of the rolled clay section is only -1 foot MLT, the COE believes a sump pump should be sufficient and that wellpoints should not be required. A bid demonstration of sump pump effectiveness should be provided for the contractors bidding on the job. The sump pump should be tested in several spots along the proposed line of construction. If the sump pump proves to be ineffective, then wellpoints would be required.
d. The equipment recommended for wet condition stone placement includes a rock drag lift or a clam. The equipment can operate from the bank or from a barge.

31. Issue: **Proposed Construction Rights-of-Way (ROW)**

a. If working in the dry, using barge terminals and not an excavated channel cut, then the 300 foot ROW should be sufficient for construction.
b. From the center line (approximately the top of the revetment slope where it meets the splash apron), the ROW extends 185 feet toward the GIWW and 115 feet toward the Gulf.
c. If an excavated channel cut (wet method) is used, then a wider construction easement will probably be needed.

32. Issue: **Benchmark Placement/Survey Control**

The contractors prefer that the Corps place monuments or temporary benchmarks every 1000 feet.

33. Issue: **Quality Control (QC) Plan**

a. The contractors would prefer that the COE <u>not</u> dictate that the contractor's QC team <u>cannot</u> perform any other function. They would prefer that the QC team not be made a totally separate organization, as is required by some COE districts. The supervisory staff should be part of the QC team.
b. The contractors felt that the restrictions placed on the QC team do not improve project quality and only serve to drive up project cost.
c. The Corps should tell the contractor he needs to be responsible for QC, but do not tell him how many people he must use to achieve it.

d. When developing QC specifications, consider the nature of the job (i.e., the majority of the work is going to be buried and subject to wave action which will cause some movement). Ensure that QC requirements provide for a stable structure, but are not unreasonable. The contract must be written with reasonable tolerances.
e. To ensure quality underwater, cross sections will be checked for conformity with specs.
f. The Corps should include partnering as part of the contract package. One contractor stated that partnering will improve quality much more than an army of QC personnel.
g. Consistent administration and application of standards from bid to project completion are more important than what the actual numbers say.

34. Issue: **Potential Chokepoints**

a. Because this project relies so heavily on logistics, transportation (particularly water transportation) is probably the biggest area of concern. The availability of transportation equipment is not the problem; interruption causing delivery delay is the major concern.
b. The risk associated with shutdown of a lock upstream is beyond the contractor's control and can become very costly.
c. The entire navigational system is considered to be a choke point. Fog and high water problems can significantly affect the delivery schedule and therefore prove costly.
d. The surge stockpile must be expanded during winter months as a hedge against weather-induced transportation delays in the spring.

35. Issue: **Material Payments**

a. Contractors felt that they should receive at least partial payment for precast armor units at the casting yard.
b. A recommendation was made to pay a certain percentage at the casting yard and an additional percentage upon delivery.
c. The percentages to be paid at various points could be determined under the provisions of a partnering relationship.
d. The general consensus was that the contractor should receive payment for completed blocks at the casting yard equal to 100% of his direct cost of production to that point.
e. An actual set price per block should be pre-determined.

36. Issue: **Special Equipment**

No special equipment is required or desired on this project.

37. Issue: **Safety**

a. No special safety requirements were identified.
b. The biggest safety concerns are expected to be crane safety, due to the fact that numerous cranes will be required on the project, and marine safety, given the fact that water transport and other marine operations are expected to play a large role in the project.
c. The consensus was that the Jones Act would apply to most injury compensation cases on the project and would boost costs.

38. Issue: **Workforce Size**

The workforce on the island during the height of construction was estimated at 25 - 30 people working on one shift. This figure does not include personnel involved in barge transportation, or off-site quarry or casting yard operations.

39. Issue: **Permits**

a. Section 404 permits will be required, at least for construction of any barge terminals on the island or for construction done using the "wet method".
b. Under EPA and/or Texas Water Commission (TWC) rules, the owner will be required to develop and file a plan for stormwater management and erosion control.
c. The contractors' preference is for the COE to develop the plan and get it approved by the EPA and/or TWC as required. The actions to be required of the contractor in order to comply with the plan should then be detailed in the contract documents upon which bids will be based.
d. If the COE does not develop this plan and get it approved by the appropriate agencies prior to putting the project out to bid, then the contractors will have no way of knowing what will be required of them, and so would have a difficult time incorporating this into their bids. The only alternative would be for them to include a sizable contingency for this work in their bids, which would probably result in higher overall project costs than if the COE developed the plan.
e. The consensus was that the project would get off to a better and faster start if the COE obtained these permits, perhaps concurrently with the real estate acquisition process.

40. Issue: **Support Facilities**

a. No special support facility requirements were identified.
b. Commercial power, telephone, and water sources already available on the island were thought to be sufficient to support the project.
c. No fixed equipment maintenance facility is envisioned. Any required equipment maintenance or repairs would be done at the equipment's location. Equipment requiring extensive repairs would be evacuated off-site as needed.
d. Haul equipment would be parked on the haul road when not in use.

41. Issue: **Calculation of Spoil Bank Location**

a. It was pointed out that a fairly detailed engineering calculation would be needed to determine how far from the edge of the excavation the spoil bank should be located so as to avoid slope failure and slides.
b. The two options for determining this were to have the COE determine this and specify it in the contract documents, or to leave it up to the contractor to determine .
c. The contractors' preference was to leave it up to them to determine.

42. Issue: **Macro and Micro Cycle Times**

a. The logic diagrams used thus far in the computer modeling by CII were reviewed with no suggested changes noted.
b. No cycle times were offered. The recommendation was to use the Caterpillar handbook, but to reduce the production rates listed there somewhat, as the consensus was that the handbook was overoptimistic.

43. Issue: **Maintaining Equipment Stability**

Mats would probably be required underneath cranes, excavators, and other equipment in order to maintain stability while working, given the generally poor soil conditions found on the project site.

44. Issue: **Heavy Equipment Required**

For a contractor using the dry method, the following equipment, as a minimum, would be required:

- 1 dragline excavating the hole for the revetment and casting the spoil aside
- 1 dragline or hydraulic excavator placing the blanket stone
- 1 dragline placing the core stone

- 1 crane placing the armor stone
- 1 dragline backfilling the excavation

45. Issue: **Labor Source**

a. The expectation is that all labor would be brought in for the project, with little if any local labor used.
b. No contractors envisioned establishing a work camp or using crew barges.

46. Issue: **Weather-Related Risk**

a. Four cost items associated with weather-related shutdowns were identified:
- Cost of moving equipment off the island or to a safe harbor
- Cost of overhead expenses during a shutdown
- Damage to completed work
- Damage to work in process

b. It was generally agreed upon that, given an estimated 3 year construction period and the project location, the problem of a project shutdown due to a weather-related event such as a hurricane was likely to be encountered.
c. One guideline offered for determining who should bear the risk was "If a contractor can't reasonably obtain insurance for it, it should be force majeure".
d. The contractors felt that the owner should bear the risk for damage to completed work. Making the contractor bear this risk will lead the contractors to include a hefty contingency for this item in their bids, thus meaning that the owner will definitely pay for this whether damage is incurred or not, whereas having the owner assume this risk up front means that the owner will only pay for it if it actually occurs.
e. The contractors also felt that the owner should bear the risk of damage to work in process.
f. The issue of who should have the responsibility for ordering a project shutdown due to an impending weather threat (i.e. hurricane, tropical storm, etc.) was discussed at great length. Having the COE responsible for ordering a project shutdown would open the COE up for liability if a shutdown was ordered too late and damage to a contractor's equipment, etc. was incurred as a result. Shutting the project down too early would also entail significant costs and could constitute disruption.
g. One option for dealing with this problem is to let the contractor assess the risk of weather-related shutdowns and include this in his bid. This would also entail making the contractor responsible for deciding when to leave or shut down the project.
h. A second option for dealing with this problem is to have contractors include weather-related mob/demob, shutdown, and repair costs as bid items.
i. A third option is to specify in the contract documents that weather-related damages/costs will be paid on a time and materials basis.

j. One method of reducing the scope of the problem of assessing responsibility for damage to work in process is to make the "acceptance station" relatively short, on the order of, say, 100 or 200 feet, rather than 1/2 mile or 1 mile.
k. In the event of a hurricane, the construction contractor would suspend operations and attempt to move all personnel and equipment to the nearest safe harbor (probably Freeport). Cranes and other heavy equipment would be loaded onto barges and evacuated.

47. Issue: **Test Driving Piles Prior to Bidding**

The contractors felt that it would be helpful if the COE were to test drive some piles and allow interested bidders to observe if performance specs for this portion of the work were to be employed, but that this would not be needed if the COE is going to assume the risk by using procedural specifications.

48. Issue: **Subsurface Data For Bidding**

a. The contractors stated that they did not feel that doing bore holes every 300 feet in areas requiring piling would provide sufficient information upon which to base a bid.
b. The contractors requested cone penetration test results at each station requiring piling.

49. Issue: **Insurance Required**

a. The contractors identified the following types of insurance as likely to be used on this project:
- Workers Compensation
- Equipment
- Marine Insurance, on leased and owned equipment
- General Liability

b. Some contractors felt that builder's risk insurance could be obtained for this project, but that it would be very costly. Builder's Risk insurance would be procured probably only if the COE mandated it.

50. Issue: **Subcontractors**

a. The contractors in attendance did not foresee a large number of subcontractors being employed on this project.
b. The possible subcontractors are:
- Landscaping
- Portable toilets

51. Issue: **Bid Period**

a. The consensus was that a 30 day bid period, commencing after issuance of plans and specs, was appropriate, with additional time given for addenda as required.
b. During this bid period, the following demonstrations should be given to those contractors who bought plans and specs:

- A demonstration of the seepage into several test excavations in order for the contractors to evaluate the scope of the dewatering problem, if any, they can expect to encounter, particularly in the sheet pile and rolled clay sections.
- Test driving of piles in those areas requiring piles, if performance specs for this portion of the work are used. This demonstration will enable contractors to evaluate the problems they can expect to encounter in driving piles in these areas, particularly to determine if predrilling will be required.

52. Issue: **Bid Basis**

a. The following were offered as the preferred bases for bids:

- Armor Stone :	Each
- Blanket Stone:	Ton, Barge Measure
- Core Stone:	Ton, Barge Measure
- Geotextile:	Square Yard
- Excavation:	Cubic Yard of Excavation
- Piles:	Per Pile
- Pile Cap:	Per Linear Foot of Pile Cap

A couple of contractors, however, felt that piling should be priced per linear foot installed, and not on a per pile basis, due to problems they expect would be encountered.
b. The general consensus was that barge measure was a fairer method of measuring the amount of core and blanket stone in place, since this would account for poor foundation soil conditions which could require more stone due to settlement.
c. One contractor pointed out that if granite is allowed as an alternative to precast concrete blocks, it is typically measured by the ton.
d. One contractor stated that the COE might want to consider measuring the armor units by barge measure as well.
e. The price for excavation should include excavation, stockpiling, and backfilling.
f. Excavation for areas requiring compacted backfill should be priced separately from excavation for areas not requiring that the backfill be compacted to any particular standard.
g. The specifications must clearly state the amount of grading required after backfilling any excavations.

53. Issue: **Scheduling**

a. Some contractors said they employed CPM schedules on every project and would do so on this project whether it was required or not. Others said that they did not really see the need for CPM scheduling on this project since they regarded it as being very simple, and would do a CPM only if expressly required to do so.
b. Several of the contractors said they did not have a problem with the COE's requirement to do a schedule on a project like this, but that what they did object to was the months-long process of meetings, etc. typically required to get a schedule approved.

54. Issue: **Project Acceleration**

a. Two options were identified for accelerating the work on this project if, for some reason, the work had fallen behind schedule:

1st Choice - Work overtime or add additional shifts
2nd Choice - Open additional work faces by bringing in additional crews and equipment.

b. Adding additional shifts could be done almost instantaneously, but opening additional work faces would require a 2-3 week logistics buildup first.
c. Opening additional work faces would entail costs basically equivalent to a second mobilization.

55. Issue: **Mobilization**

a. The COE typically pays 60% of the mob/demob cost upon mobilization and 40% upon demobilization.
b. One contractor reported that he is currently working on a COE project that is being paid on an 80/20% basis.
c. The contractors felt that 75% In/25% Out would be appropriate on this project due to the large amount of materials and equipment that will have to be moved to the site in order to start the project.

56. Issue: **Incentives/Liquidated Damages**

a. Several contractors said that they felt that incentives were appropriate on projects where the owner would benefit from early completion of the project, and that such incentive clauses did spur them to finish the projects earlier in order to get those incentive payments.

b. There was no call for early completion incentives on this project since no one could identify how the owner would benefit from early project completion.
c. Several contractors remarked that it usually cost a contractor much more of his own money for overhead expenses if a project is late than he is assessed for liquidated damages. No one stated, however, that they felt that liquidated damages would be inappropriate on this project.

57. Issue: **Partnering**

a. The contractors who had partnering experience, with the COE or other owners, said it was definitely a worthwhile effort.
b. The participants were informed of the results of a recently completed thesis done by a UT graduate student that documented the positive benefits of partnering on COE projects.
c. No obstacles to a successful partnering effort on this project were identified.
d. Several contractors noted that the project designers on this project should be included in the partnering effort, and not just the project engineer and inspectors responsible for administering the construction contracts. Involvement of the designers in the partnering effort will go a long way to successfully resolving any questions or problems that may arise on the project.
e. Among the particular issues that the contractors felt partnering would help resolve, and thus help avoid disputes, were:

- verification of mob/demob expenses
- resolving weather-related damages and expenses
- differing site conditions
- sheet pile installation, etc.

f. The possible relocation of the design section from Galveston under the COE reorganization was mentioned as possibly complicating the involvement of the designers in the partnering effort. The consensus was that it was an important enough issue that this should not be permitted to be an obstacle to their involvement.

58. Issue: **Alternative Dispute Resolution**

a. Partnering should reduce the need for dispute resolution.
b. The claims potential for this project was rated as low - moderate, but would depend on such things as:

- the size of the acceptance area as it relates to a contractor's exposure for damage to completed but not yet accepted work
- the project specifications, particularly with regard to the quality standards developed for the project
- the inclusion of and design and specs for the concrete sheet piling

c. The claims potential for the project should be lower if the concerns brought out in this constructability review are addressed by the designers.
d. Mediation was offered as an appropriate means of dispute resolution. The advantages are that it is reasonably inexpensive and nct too time consuming. Its use should be spelled out in the contract documents.
e. The COE cannot accept the use of binding arbitration, but all other means of ADR are at least options.
f. Dispute Review Boards can be a crutch for weak project management, either on the part of the owner or contractor.

59. Issue: **Computer Simulation**

a. The contractors are not familiar with the capabilities of the computer modeling system being employed by CII in the study, and so cannot say whether it would be helpful to them or not.
b. Several said they had open minds about its use and were at least willing to take a look at the results produced to evaluate its utility.
c. One contractor questioned if computer simulation constituted a bit of overkill, on what he saw as a relatively simple and straightforward project.

60. Issue: **Contract Administration**

a. The project is expected to be administered by the Galveston District's Construction Division.
b. The project engineer and inspectors would probably work out of a project office located on the island. Providing project office space will probably be included in the contractor's scope of work.

61. Issue: **Plus/Delta Analysis of the Meeting**

a. A plus/delta analysis of the meeting revealed the following positive elements and elements requiring improvement:

Positive:
- The fact that a constructability meeting like this was held to give the contractors input into the project.
- The contractor input should result in an improved design for the project.
- A good cross-section of the industry was represented at the meeting.
- Much input was gathered for inclusion in the CII report.
- Potential problem areas with the design were identified.

<u>Needs Improvement:</u>
- More lead time to prepare for the meeting
- More senior representatives from the COE should have attended, possibly including the District Engineer, to hear contractor concerns first hand.
- Design and construction administration representatives should have attended, both to hear contractor concerns first hand, and to facilitate a two-way dialogue with the contractors.

62. Issue: **Usefulness of Constructability Reviews**

a. All present felt that the day was well spent and that a better project for all concerned should result from the effort.
b. Constructability conferences such as this one would yield even greater benefits if applied to more complex projects.

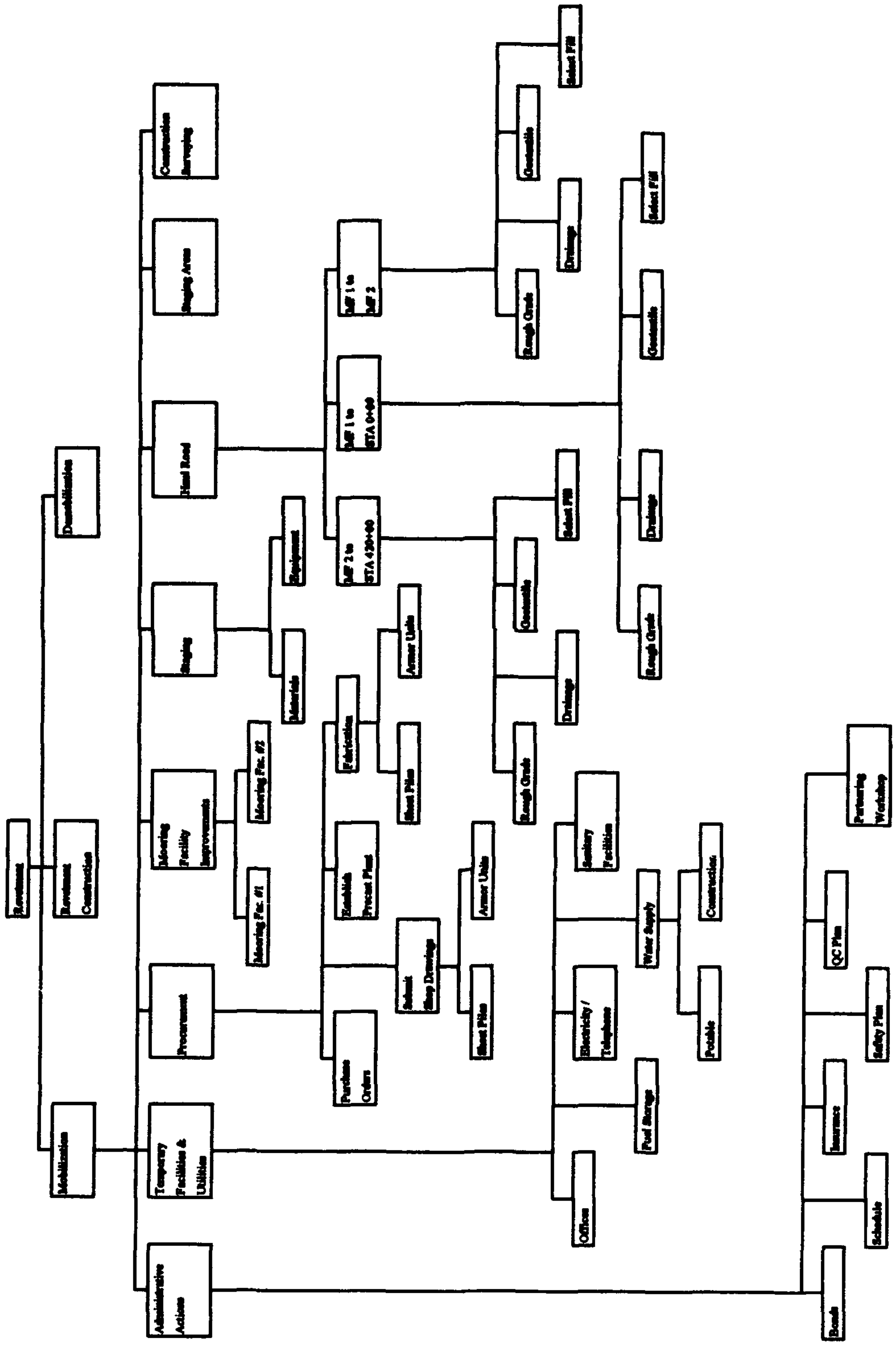
63. Issue: **Follow-up Meeting**

a. Many of the contractors expressed interest in being able to provide additional input to the project, and to hear the outcome of the issues that were raised in the meeting.
b. An attempt will be made to have another meeting to afford the contractors an opportunity to review and comment on the recommendations contained in the CII report before it is submitted to the Galveston District O/A 1 Sep 93. The target date for such a review is Aug 93. As an alternative to another meeting, copies of the draft CII report would be circulated for review and comment.

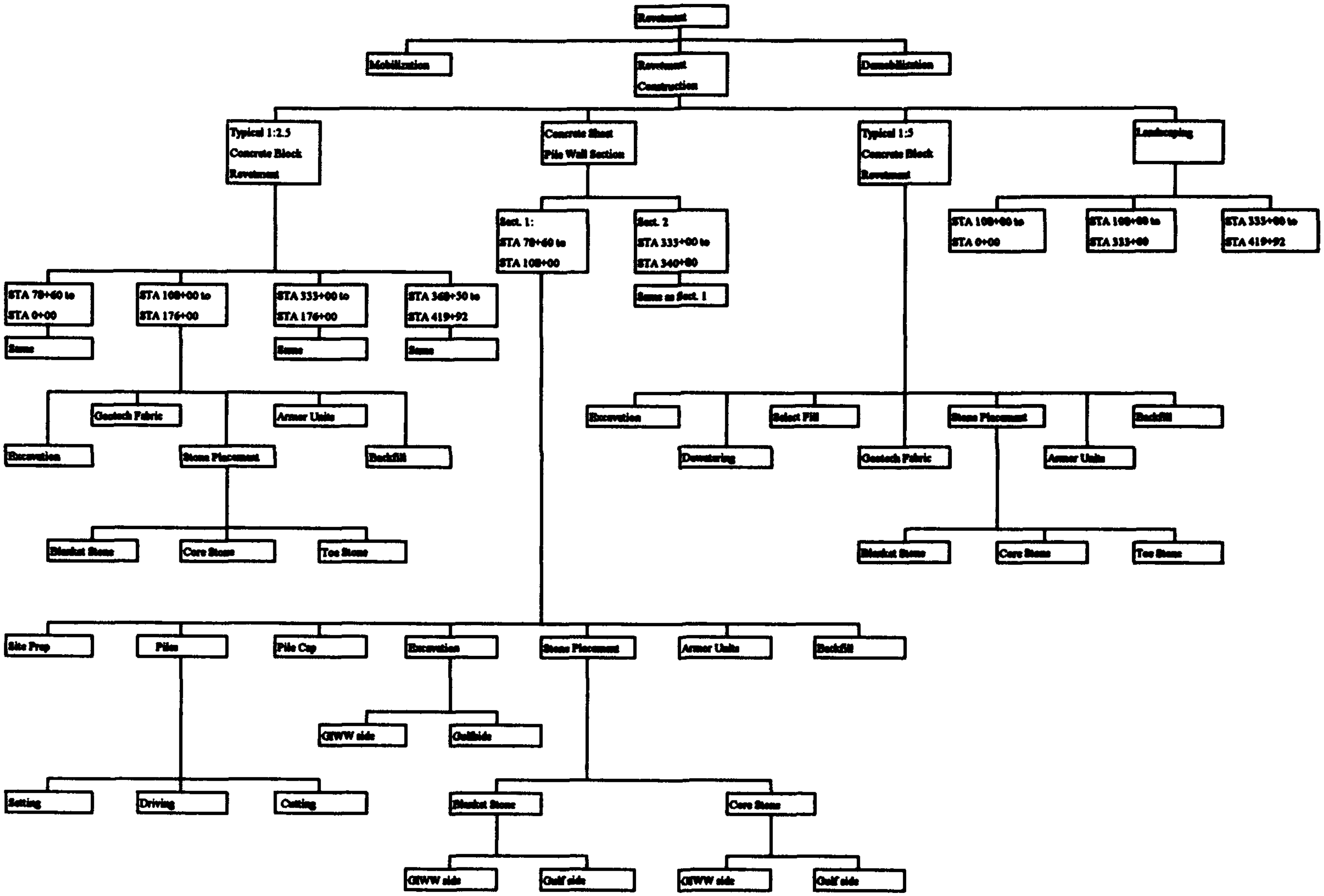
64. Issue: **Availability for Follow-up Questioning**

The contractors indicated a willingness to answer additional questions if need be and were agreeable to being contacted by the CII researchers as required.

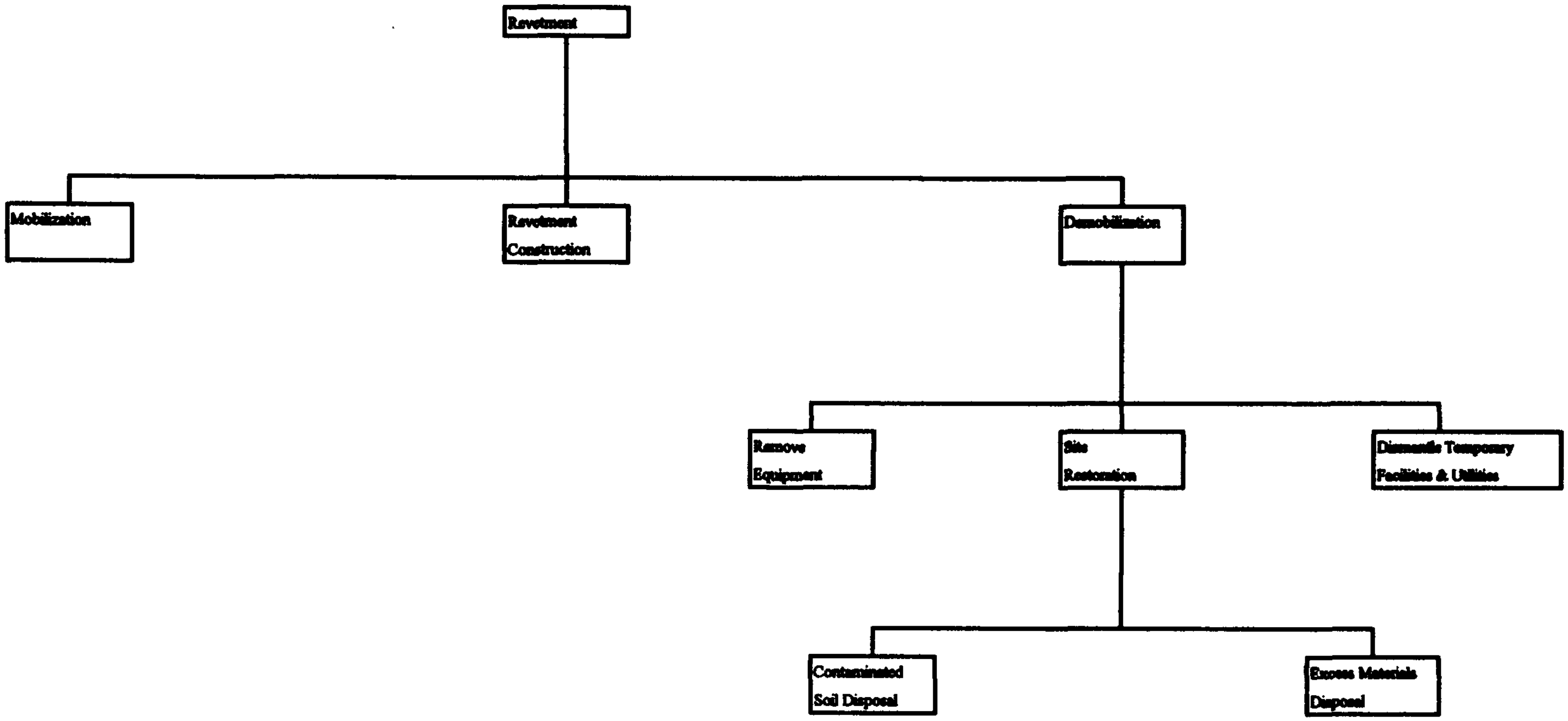
Appendix D: Work Breakdown Structure



Work Breakdown Structure - Mobilization



Work Breakdown Structure - Revetment Construction



Work Breakdown Structure - Demobilization

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